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SUPPLEMENT: THE STRUCTURE AND PROPERTIES OF DIAMOND
BY SIR C. V. RAMAN

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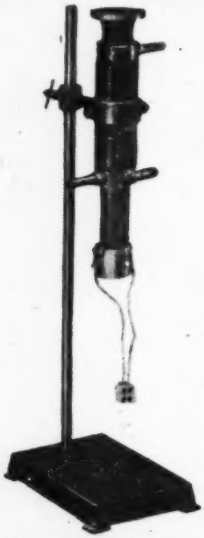

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CURRENT SCIENCE

Vol. XII] JANUARY 1943 [No. 1

	PAGE
Problems of Post-War Agricultural Reconstruction. B. VISWANATH ..	1
Sir Jnanchandra Ghosh, Kt., D.Sc., F.N.I.	3
Rao Bahadur B. Viswanath, F.I.C., C.I.E.	4
Dr. W. R. Aykroyd, C.B.E., M.D., Sc.D. ..	5
Sir S. S. Bhatnagar, Kt., O.B.E., D.Sc., F.Inst.P., F.N.I.	5
Gracious Message from H.H. The Maharaja of Mysore to the Eighth Annual Session of the Indian Academy of Sciences ..	6
Science and the Censor	6
Discovery of Deposits of Sodium Sulphate at Didwana. BY H. B. DUNNICLIFF, C.I.E.	7
Obituary—	
Prof. Richard Willstatter	12
Embryology of Orchidaceæ. BY B. G. L. SWAMY	13
Letters to the Editor	18
Reviews	27
Land Management in the Punjab Foothills. GILBERT J. FOWLER	29
Centenaries—	
Potter, Nathaniel (1770-1843) ..	30
Fitch, John (1743-1798)	30
Science Notes and News	31
Supplement: The Structure and Properties of Diamond. BY SIR C. V. RAMAN ..	33

PROBLEMS OF POST-WAR AGRICULTURAL RECONSTRUCTION

AFTER the war is over and peace is restored, there will arise problems of social and economic repair and reconstruction. Agricultural reconstruction will have to receive prior consideration. Farming will be the first to be re-established in the areas that have suffered from war and being also the occupation of the bulk of the world population, the reconstruction of agriculture is the basis of national reconstruction. These tasks which should be considered well in advance of the need, demand expert knowledge, careful thought, clear vision and planning with foresight.

The lead given by the British Association for the Advancement of Science is, therefore, none too early. Through its Division for the Social and International Relations of Science, the Association arranged, in March this year, a Conference for the discussion of plans for the post-war reconstruction of agriculture in Europe. A large number of experts from the different countries of Europe participated in the Conference and made valuable contributions. Although the discussions were chiefiy on plans for the re-establishment of agriculture in the devastated and oppressed areas of Europe and on the alleviation of the effects of famine and disaster, it was recognised that in the general problem of reconstruction the solution of immediate problems were closely interwoven with long-term policies and that, therefore, urgent plans should be linked up with long-term plans.

India, like Europe and the rest of the world, will have her post-war problems. A merciful Providence has so far spared India the horrors and disasters which her less fortunate sister-countries are suffering from. And so, her immediate post-war problems may not be similar to those of Europe and other Eastern countries of Asia. But linked up as she is with the outside world and its affairs, she has to play an important part directly or indirectly in the re-establishment of agriculture in the devastated areas. She has also her own urgent and long-term socio-economic and socio-political problems of reconstruction, special

and peculiar to herself and in dealing with these, her plans of reconstruction have to be in consonance with world policies.

The situation arising out of current war conditions such as changes in cropping systems necessitated by loss of export markets for certain crops and by the "grow more food" campaign, and the effects of inadequate nutrition and disease will need technical examination and practical adjustments as and where necessary. Occupation and instruction in matters of agriculture, village and domestic welfare, will have to be provided for the peasant-soldier returning from war.

Since the beginning of the century, the Central and Local Governments have been paying systematic and sustained attention to agricultural and rural development. After the experience of the devastating famines of the last century followed by epidemics and loss of life, an agricultural policy was laid down. Research institutions were established for the scientific study of agricultural and livestock problems. The realisation of risks to agricultural industry through drought and erratic rainfall resulted in an irrigation policy and network of irrigation canals in various parts of the country. A Land Improvement Loans Act and an Agriculturist Loans Act were enacted as early as 1883 and 1884 to counteract agricultural indebtedness, and a further measure in this direction was the passing of the Co-operative Credit Societies Act in 1904 on the recommendation of the Famine Commission of 1901. With the advent of popular Governments following the Reforms Acts of 1920 and 1935, rural development and rural reconstruction came into prominence in recent years. Not only the Central and Local Governments began to take a more active interest in the work of rural uplift but some of the social and political organisations have made it part of their programme. As the result of research, intractable waste lands have been conquered, crop yields have been increased, and good breeds of work and milch cattle have been developed.

The net result is that several government departments and non-official organisations have been actively concerning themselves with the welfare of the village and the farmer. The results achieved are imposing. If more and quicker results have not been achieved, that is due mainly to causes which although beyond the control of individuals, are nevertheless, within the nation's power to remedy.

The present social and economic system in the country and the relation between production and distribution are ill-balanced. Village life should be enriched by suitably moulding the prevailing social and economic order including systems of land tenure and occupancy, so that work and worker are brought together and people may create wealth by their own efforts. As one member said at the Conference on European Agriculture, the basis for reconstruction is the realisation that man is more important than the soil. The restoration and maintenance of individual self-respect, self-reliance and a healthy condition of mental and spiritual health is of paramount importance.

The increase in the population and its pressure on land are vitally concerned in the problems of reconstruction. From the standpoint of food and nutrition there is no need for alarm or anxiety. Our agricultural resources, provided they are properly husbanded, can be depended upon to feed not only the present normal population and the population which has now to stay away in the country owing to the stoppage of emigration, but also the emigrant population that has returned. The country can find food for even more. In regard to the standard of living it is really the standard of the home and any rise in the standard can come principally from the standard of the village and this is closely connected with the balance in production and distribution, with the spread between agricultural and industrial prices, educational facilities and the training of the young.

The greatest and the most difficult of the problems are those arising from the laws and customs of inheritance and the division of land. The division into small holdings has gone on to such an extent that in many cases farming has ceased to pay and is carried on in the absence of something better. Because of this, the purchasing power of the farmer is reduced. Agricultural improvement is hampered, unemployment is increased and in consequence the standard of living and nutrition falls to a low level. Consolidation of holdings and collectivisation as a remedy are not without their drawbacks. The possible consequences are increase in unemployment,

loss of individuality, and despair and discontent taking the place of the sense of pride in ownership and possession. The key problem is the problem of small holdings and peasant agriculture.

Crop-planning is not likely to be helpful in counteracting the evils of small holdings. In the first place there is the tendency towards self-sufficiency in Provinces and States. In the second place there are likely to be difficulties in carrying out the planning. It will be difficult owing to the inherent inability of small farmers to adapt their production to the changing conditions in the economic situation and to secure a certain unity of control in production and marketing. In the case of industries and trades this can be achieved by the elimination of small producers. But in agriculture the majority of producers are small farmers and they cannot be eliminated.

The reorientation and the co-ordination of agricultural and industrial policies, which appear to have satisfactory results in Belgium seem entitled to careful consideration. As Mr. M. L. Borremans pointed out, Belgium which is one of the most highly industrialised countries, is rarely thought of as an agricultural country. Belgium, however, is a country of small holdings and according to the census of 1930, nearly three-fourths of the total agricultural holdings were less than two and a half acres in size. These small holdings which are scattered all over the country and amongst which industries and factories are located, operate as part-time holdings. According to Mr. Borremans, the part-time holdings are a special feature of social conditions in rural Belgium constituting a semi-agricultural and semi-industrial unit in which agricultural and industrial life are intermixed. The real characteristic of part-time holdings is that the family in a village is split up between agriculture and industry, and not that it is working at certain times on the farm and at other times in industry.

The farmer is becoming more and more self-conscious. His thinking has undergone a new orientation. He needs more income and more buying power. The masses of people expect and demand to be fed, clothed and housed better than before. An awakened peasant population and masses cannot be expected always to think cogently and act wisely. Nor can they be expected to have the patience to wait long if not indefinitely. Small holdings and peasant agriculture are the key problems and further progress is possible in proportion as solutions are found to the key problems. They have to be thought out and planned in advance if results are to be attained peacefully and successfully.

B. VISWANATH.

SIR JNANCHANDRA GHOSH, Kt., D.Sc., F.N.I.

AMONGST the men of science in India included in the New Year Honours List *Current Science* notices with great pride and pleasure the name of Dr. Jnanchandra Ghosh, who has been knighted.

It is not easy for this *Journal* to give either formal or adequate expression of congratulations and good wishes to the distinguished recipient of the honour because, Sir J. C. Ghosh is an integral part of *Current Science* itself—being the President of the Current Science Association which runs this periodical. Both in this capacity and otherwise, Sir J. C. Ghosh's counsel, support and influence have nourished and sustained *Current Science* which, like any other young and growing institution in its early years, has not been without its teething troubles.

Nor is this the occasion to take stock of Sir J. C. Ghosh's scientific achievements and his service to Indian industry. Reticence which is imposed and inevitable during the war must necessarily preclude a full picture being drawn of his great contribution to the gearing of scientific research to industry during the last three years. Happily, Sir J. C. Ghosh is young enough to look forward to many more years of scientific endeavour which, all those who know him have no doubt, will be rich in achievement.

Sir J. C. Ghosh's contacts with Indian science and industry have been unusually many and varied. As a teacher of science and a mentor of schools of research, as the director of the foremost Indian institution devoted to science, as one of the earliest members of the Indian Science Congress which has honoured him by electing him to the highest offices in its gift and as a

member of a very large number of academic bodies, committees and organisations which initiate, organise and finance Indian scientific research, publish the results thereof and shape policy in correlating the results of research to the needs of agriculture and industry, Sir J. C. Ghosh has played a leading part during the last two decades. And in every one of these many diverse fields, his personal qualities and quiet charm of manner have won for him the loyalty, esteem and friendship of a host of admirers.

It is characteristic of Sir J. C. Ghosh's innate modesty that at the first public meeting he took part after being knighted (as President of a meeting of the South Indian Science Association on January 11, 1943), he said that he preferred to consider the honour not as a personal distinction but as a tribute to all those who shared in the scientific endeavour centred at Bangalore. *Current Science* can think of no more appropriate wish on this happy occasion than to say: May scientific endeavour in Bangalore continue to be honoured thus for many, many more years to come!

RAO BAHADUR B. VISWANATH, F.I.C., C.I.E.

THE happy news that Rao Bahadur Viswanath, Offg. Director, Imperial Agricultural Research Institute, New Delhi, has received the distinction of C.I.E. will be read with immense satisfaction by his numerous friends and colleagues in the scientific world. Rao Bahadur Viswanath is a pioneer in agricultural research and has been responsible for building up a

strong and enthusiastic school of agricultural science both at Coimbatore and now at Delhi. His work on the effect of farmyard manure in raising the vitaminic potency of the crops raised on it, remains one of the classical pieces of work carried out by him.

During the post-war period of the last World War, Rao Bahadur Viswanath played a prominent part in helping the agriculturists to grow more food by the application of phosphatic manures, and by the adoption of scientific methods of agriculture. To-day he is at the helm of the Imperial Agricultural Institute, and with the unbounded energy

and vigorous drive characteristic of him, he is organising the 'grow more food campaign' not only to obtain food materials in quantity but of a quality which will keep the nation free from hunger and free from disease. This is the greatest service which any scientist can render to his country.

We wish to offer him our heartiest felicitations on the honour he has won and wish him a long and eventful career of greater achievement and higher distinction.

DR. W. R. AYKROYD, C.B.E., M.D., Sc.D.

IT is a great pleasure to offer Dr. Aykroyd our felicitations on the occasion of the conferment of the C.B.E. in the New Year Honours list. Dr. Aykroyd succeeded Sir Robert McCarrison in 1935 as the Director, Nutrition Research Laboratories, Coonoor. Prior to this appointment, while working in the Health Section of the

League of Nations, he wrote in collaboration with Dr. E. Burnet, the report "Nutrition and Public Health", which won him international fame in the field of nutrition. Dr. Aykroyd is a member of the Technical Commission on Nutrition of the League of Nations. In India, the credit of systematic analysis of various Indian foodstuffs and also of initiating, all over the country, filed experiments in practical nutrition especially with school children, goes to Dr. Aykroyd. He is also responsible for starting propaganda work in the field of nutrition, setting up a fine museum in the Laboratories and also starting a training course in nutrition for health officers, which attracts persons from different parts of India every year. Dr. Aykroyd has published two books on nutrition and numerous scientific papers. We wish Dr. Aykroyd a long life and many more distinctions to crown his labours.

SIR S. S. BHATNAGAR, Kt., O.B.E., D.Sc., F.Inst.P., F.N.I.

WE are happy to announce that Sir S. S. Bhatnagar has been elected an honorary member of the Society of Chemical Industry, London, in recognition

of his *"manifold contribution to knowledge and his selfless devotion to scientific and academic duties"*. We wish to offer him our respectful felicitations on this distinction.

GRACIOUS MESSAGE FROM H. H. THE MAHARAJA OF MYSORE TO THE EIGHTH ANNUAL SESSION OF THE INDIAN ACADEMY OF SCIENCES

The Palace,
Mysore,
22nd December 1942.

I have heard with great pleasure that the Eighth Annual Meeting of the Indian Academy of Sciences is to be held at Bangalore under the distinguished presidentship of Rajasabhabhushana Sir C. V. Raman. The publications and periodical meetings of the Academy and other similar bodies are serving as a clearing house of information relating to the researches undertaken by scientific workers in India. By coming together and comparing results and experiences from time to time, they are enabled to pursue their respective lines of study with increased confidence and in a spirit of mutual collaboration, and there is every ground for the hope that Indian scientists will continue to make substantial contributions to the stock of scientific knowledge. The Academy is also striving to make the lay public realise the importance of scientific research as an instrument of human progress and happiness, and its efforts in this direction deserve encouragement.

I wish the Conference all success.

(*Sd.*) JAYACHAMARAJA WADIYAR.

SCIENCE AND THE CENSOR

SCIENTISTS in general and physicians in particular will be disturbed by the correspondence which has passed between the postal censor and Dr. J. McKeen Cattell, Editor of *Science*, and which appears in the current issue of that Journal. That censorship in war is necessary no one will deny. But was the censor justified in deleting from *Science* an item on a new sulfa drug which can be used with good effect in such intestinal infections as dysentery, because our enemies in tropical regions might learn how to return the afflicted men rapidly to the fighting line? From time immemorial military surgeons have made no distinction between friend and foe in dealing with wounds and disease. In 1917 both the Surgeon-General of the Army and the Secretary of War decided that for humanitarian reasons publication of information about an antitoxin developed in this country to combat the bacillus of gas-gangrene, then highly destructive on the Western Front, was permissible. Thousands are now dying of typhus in occupied Middle Europe, but if the censor has his way they cannot be saved by the dissemination of any new knowledge acquired here.

We detect no such narrowness of view in the few German medical and scientific publications that have reached this office since the attack on Pearl Harbor, nor in the pages of *Nature*, which is apparently permitted to exercise its discretion and which prints communications of the very type that have ben expunged from *Science*. The censor was certainly on slippery ground when he deleted references to indium because that metal can provide a satisfactory lining for shaving-cream and tooth-paste tubes. The Germans know as much about indium as we. So with the suppression of an item on a method of spraying walls of mines to prevent mercury poisoning. Some of the material to which the censor objected in the case of *Science* had been published in newspapers from Maine to California, so that nothing whatever was gained by deletion. To make matters worse, there is no appeal from this decision.

Probably Dr. Cattell is right in holding that the editors of scientific periodicals are better judges of what may or may not be of value to the enemy than technically incompetent postal authorities. If the policy to which he objects is carried out consistently, new scientific books and periodicals must be suppressed. Astrophysicists, biologists, plant and animal breeders, organic chemists who are trying to isolate vitamins and harmones, designers of new electron microscopes, inventors of materials that will resist fire, mathematicians who devise techniques that can be applied in solving the problems of designing engineers—all make discoveries that have some application in totalitarian war.

—*The New York Times.*

DISCOVERY OF DEPOSITS OF SODIUM SULPHATE AT DIDWANA

BY
H. B. DUNNICLIFF, C.I.E.
(Chief Chemist, Central Revenues)

WHEN the author was on a visit to Sambhar Lake in November 1940 in connection with an investigation into the possibility of exploiting the sodium sulphate and sodium carbonate deposits in the East Lake Bitterns Area,[1] the General Manager, Rajputana Salt Sources gave him a sample of 'pan scale' from Didwana, a salt source in Jodhpur State, about forty miles north-west of Sambhar.

'Pan scale', also called 'papri', is formed by the evaporation to dryness of the bitterns which remain after the manufacture of edible salt from subterranean brine at that place and it contains a high percentage of sulphate. When the General Manager received the analysis of this pan scale (Table I, Sample I) showing 85 per cent. of sodium sulphate, he expressed considerable surprise stating that the last reported analysis (*ibid.*, Sample II) in 1933 showed a much lower sulphate content and he suggested that another sample should be examined. The writer reported on this in January 1941 (Sample III) and expressed the view that this material might provide a good source of sodium sulphate for which there is a considerable and constant demand in India.

The matter was reported to the Central Board of Revenue and when Mr. R. K. Nehru, I.C.S., Collector, Central Excises and Salt, North-Western India, visited Didwana in the following March, he sent a number of samples of 'papri', collected from different pans, for analysis. These samples which varied very widely in sulphate content were mixed, the average analysis being shown in Table I, Sample IV.

TABLE I
Didwana Papri

	Sample I %	Sample II %	Sample III %	Sample IV %
Insolubles ..	0·27	2·80	0·56	3·14
Sodium chloride ..	13·05	69·18	19·26	65·04
Sodium sulphate ..	85·22	20·28	78·00	29·50
Sodium carbonate ..	0·70	6·78	0·58	0·35
Sodium bicarbonate	0·76	0·08	0·84	0·41
Undetermined and moisture ..	—	0·68	0·76	1·56

This very wide range of composition of papri or pan scale is not unusual, individual samples collected containing from 18 to 80 per cent. of sodium sulphate. This is explained by the method of formation of the papri which will be clearly understood from the description of Didwana salt manufacture given later, and the subsequent discussion.

The Collector proposed to ascertain if some industrial use could be found for papri of which, at the present scale of salt manufacture, about 15,000 to 20,000 maunds would be available annually. Mr. J. M. Saha, M.Sc., C.R.C.S., Chemical Examiner, Central Excises and Salt, North-Western India, expressed the view that a salt having the composition of Sample No. IV, Table I, would be very suitable for curing hides and skins. The Collector asked him to submit a further report on the possibilities of Didwana papri and, with this object in view, he visited the Didwana Salt Works in May 1941.

Although by this visit Saha did not improve on his previous report on 'papri', he made a valuable contribution to India's industrial development in the discovery of a plentiful source of high grade, naturally occurring sodium sulphate and, in reconstructing its genesis, devised an improved method for the manufacture of high quality salt from Didwana brine.

Saha observed that the beds of the crystallising pans were formed of a thick crust of a very hard crystalline substance called "rohr" which was reported to be as much as three feet deep in some places.

Samples drawn from two different pans had the following composition.

TABLE II
Didwana Pan-bed Crust or 'Rohr'

	I (%)	II (%)
Inorganic insolubles	11·90	5·98
Organic insolubles	0·52	0·30
Sodium sulphate	82·74	93·17
Sodium chloride	4·50	0·40
Undetermined	0·34	0·15
Sodium sulphate on water soluble components	94·84	99·56

According to Saha's most recent calculations, over fifty lakh maunds and possibly a crore maunds of rohr are available for recovery.[2] About 3,000 tons of the rohr, very rich in anhydrous sodium sulphate, have recently been excavated from a few pans with a view to commercial exploitation, and Table III gives analyses of samples from different depths of a particular deposit.

TABLE III
Didwana Pan-bed Crust or "Rohr"

	Top sample %	Middle sample %	Bottom sample %
Insolubles	0·40	1·08	0·35
Sodium chloride	1·10	1·10	1·46
Sodium sulphate	98·11	97·50	97·50
Sodium carbonate ..	0·11	0·13	0·13
Sodium bicarbonate ..	0·11	0·21	0·34
Moisture	0·16	0·21	0·31
TOTAL ..	99·99	100·23	100·09

The Government of India are operating the Didwana Salt Works for the manufacture and sale of salt on lease under a treaty with the Jodhpur State to whom the area belongs, and the State is making arrangements for marketing this new and valuable source of salt cake.

PRESENT METHOD OF MANUFACTURE OF SALT AT DIDWANA

Salt has been manufactured at Didwana in Jodhpur State, Rajputana, from times immemorial. The salt source is an oval-shaped depression, about 4 miles long and 1½ miles broad, which generally remains dry, except for a short time during the annual monsoon.

The total area developed so far for the production of salt is 92 acres or less than 5 per cent. of the total available. Wells about 6 feet in diameter and 16 feet in depth are sunk in the depression. Kul (well) brine of unusually high density (Table IV) is found at a depth of about six feet from the surface and the supplies are said to be inexhaustible.

Round the wells, shallow evaporating pans are made of varying size and about one foot deep. Originally they had clay beds. The warm brine is taken from the wells by means of earthenware pots attached to the ends of lever lifts (chaunch).

The brine is run into the pans and is concentrated by solar evaporation and deposits salt, the multiple accretion system of manufacture being followed. The pans are charged to a depth of 1" to 2" with brine drawn from the wells. Evaporation and crystallisation take place and the pans are again charged, the same process being repeated until, after a few weeks, a thick crust of salt has been obtained. Much of the sulphate crystallises with the salt and naturally the quality of the product is poor [Table V, (*a*) and (*b*)]. Underneath this salt and in course of salt manufacture extending over many years, a hard crystal-

TABLE IV
Didwana 'Kul' (well) Brine

Density°, Be′ / Temperature, °C.	26·9° / 37·5°C. %	26° / 39°C. %	25° / 39°C. %	24° / 39°C. %	23° / 37·5°C. %	20·9° / 37·5°C. %
Sodium chloride	22·99	19·53	18·49	18·27	16·05	16·97
Sodium sulphate	5·80	5·95	6·56	5·37	7·64	4·68
Sodium carbonate	0·51	0·87	0·42	1·04	0·48	0·62
Sodium bicarbonate	0·58	0·56	0·37	0·63	0·53	0·58
Total solids	29·88	26·91	25·84	25·31	24·70	22·85
Water	70·12	73·09	74·16	74·69	75·30	77·15
The above results expressed in terms of dry matter are given below.						
Sodium chloride	76·93	72·56	71·55	72·18	64·08	74·31
Sodium sulphate	19·41	22·11	25·39	21·21	30·93	20·44
Sodium carbonate	1·71	3·23	1·63	4·11	1·94	2·71
Sodium bicarbonate	1·95	2·10	1·43	2·50	2·15	2·54
	100·00	100·00	100·00	100·00	100·00	100·00
Percentage ratio of sulphate to chloride	25·23	30·52	35·49	29·42	47·61	27·51

crystalline bed of sodium sulphate has formed cumulatively on top of the clay bed.

The manufacturing season starts at the beginning of February and continues until the middle or end of May and sometimes even later. The mother liquor (bitterns) left in the pans after the extraction of salt subsequently dries and forms into a thick scale called 'papri' (v.s.). After each monsoon, it is only necessary to remove the mud and the papri from the pans and they are again ready for the manufacture of salt.

As ordinarily manufactured, Didwana salt is very dull and unattractive in appearance; the composition of two typical samples [Table V, (*a*) and (*b*)] indicate its poor quality, the principal contaminant being sodium sulphate.

TABLE V
Didwana Salt

	As manufactured by the usual process (%)		As manufactured by Saha's process (%) (*vide* below)	
	(*a*)	(*b*)	(*c*)	(*d*)
Insoluble matter ..	0·66	0·61	0·17	0·38
Sodium chloride ..	88·76	85·61	98·24	97·52
Sodium sulphate ..	9·45	12·79	0·85	1·40
Sodium carbonate ..	0·27	0·11	0·05	0·21
Sodium bicarbonate	0·13	0·08	0·08	0·08
Moisture and undetermined ..	0·73	0·80	0·61	0·41

An examination of the composition of typical samples of brine from which the salt is manufactured (Table IV) will show that the indifferent quality of the salt made by the current method is not unexpected. The brines are of remarkably high density and the proportion of sodium sulphate to sodium chloride is very high, approximately 25 to 48 per cent.

SAHA'S THEORY OF THE FORMATION OF THE BED CRUST

On cold winter nights in February at the beginning of the annual manufacturing season, when the temperature of brine falls low, the solubility of the sodium sulphate falls sharply while that of the sodium chloride is not much affected. The solubility of the sodium sulphate is also further reduced by the presence of the sodium chloride so that, in cooling from over 80° F. (27° C.) to the cold weather temperature of about 36–40° F., sodium sulphate crystallises out as the decahydrate, Na_2SO_4, $10H_2O$ and deposits on the pan bed. This probably goes on night after night until the brine is sufficiently concentrated to deposit sodium chloride, by which time a large proportion of the sodium sulphate will have probably crystallised out. Saha thought that, up to a certain point, this separation of sulphate was specific, the hydrated salt losing water due to rise in temperature at a later stage. His conjecture was based on the composition of the samples of bed crust (rohr) which consist mainly of anhydrous sodium sulphate, remarkably free from the chloride and carbonates of sodium. The existing bed crust must have been formed by the sulphate thus separated only from the first few charges of brine fed into the pans each year. It has, therefore, taken generations to attain its present thickness. The sulphate separated in the later charges of the pans would deposit on the existing crystals of salt and thereby lower its purity.

LABORATORY EXPERIMENTS

Working on this theory of the formation of the bed crust, he conducted experiments at the Central Revenues Control Laboratory, New Delhi, on samples of impure brine brought from Didwana, which yielded very satisfactory results and confirmed the theoretical reasoning.

Using artificial refregeration, he showed that the separation of the sulphate and purification of the brine were most satisfactory at temperatures of from 36° F. to 42° F. The brine thus purified yielded samples of beautifully clear crystalline salt having as high a purity as 98 per cent. [*vide* Table V, (c) and (d)], while, from the crystalline Glauber's salt, anhydrous sodium sulphate separated when the laboratory temperature rose to summer heat.

On the results of these experiments, Saha proposed a scheme of manufacture calculated both to improve the quality of salt and to produce the valuable by-product, sodium sulphate, in commercial quantities. He suggested that the manufacturing season at Didwana should commence from the beginning of November and continue until February or March, i.e., so long as the minimum night temperatures fell below 60° F. The method proposed that a certain number of pans to be called "eliminators" should be set apart for the separation of

sulphate, the resultant purification of the brine being assisted by natural agency of the low atmospheric night temperatures prevailing at Didwana. The eliminator pans, fully exposed to the cold atmosphere, should be charged to a depth of about 4 to 5 inches and, when the maximum amount of sulphate has separated but before the crystallisation of salt has commenced, the brine thus purified should be transferred in the early morning to a separate set of "crystallising pans" where, by the day-time heat and breezes, it would be evaporated for the manufacture of salt.

The separated decahydrate would be dehydrated before marketing.

Field Work at Didwana

Experiments on a large scale were next conducted at Didwana in the months of December and January, 1941–42, using specially selected existing pans and also pans newly constructed for the purpose. The author accompanied Saha on one of his visits and was much impressed with the success of his experiments, the only major difficulty encountered being that the temperature of the hot brine never fully fell to the lower atmospheric temperature anticipated. It was observed that the desired low temperatures actually occur at Didwana during November to February but, while the minimum temperature attained at one time was as low as 21·5° F., it usually varied between 32° and 40° F., while the brine temperature always remained about 15° F. higher than the minimum atmospheric temperature recorded. As a result of this and in spite of the very low range of atmospheric temperatures, the separation of sulphate and the purification of the brine were not so effective as Saha expected nor as complete as was promised by his laboratory experiments. He is of opinion that this is due to the fact that the natural temperature of the ground is high and that its radiation prevents the temperature of the brine from falling to the atmospheric level. In order to circumvent this difficulty, he has suggested that the eliminator as well as crystallising pans should be constructed on a special type of bed.

On the whole, however, the results obtained were very satisfactory and the process is undoubtedly workable and easy of operation even by the illiterate local salt manufacturers (deswals). Thus, apart from the discovery of this rich and plenteous source of sodium sulphate which should be sufficient to meet India's entire demand for some decades to come, the new method devised for the production of an improved quality of alimentary salt would simultaneously ensure the annual production of sodium sulphate on a large scale.

It has been found that, for every lakh maunds of salt produced, 15 to 20 thousand maunds of anhydrous sodium sulphate will be available. The average purity of the salt and the sulphate thus produced will be 97–98 and 97 per cent. respectively.

Saha's process has the great merit of simplicity in execution and in the words of the Collector "it kills several birds with one stone". A better quality of salt could be placed on the market, the season could be extended resulting in higher production and unemployment amongst the deswals would be relieved. Didwana would also increase in importance as a source of alimentary salt, the dependence on Sambhar for salt in the North of India being thereby considerably reduced and a valuable and much wanted industrial bye-product would be obtained in quantities. This annual supply of sodium sulphate would be supplementary to the rohr deposits mentioned earlier in the paper and the total output should satisfy India's entire demand for salt cake.

This scheme of salt manufacture will not interfere in any way with the normal recovery of the ordinary quality salt. This, as in current practice, should be started in February or March using the same pans after the winter manufacturing season is over. The deswals will thus remain employed for the greater part of the year to their great economic benefit.

The Theoretical Explanation of the Didwana Deposits and Saha's Process

Ignoring the small percentage of carbonates present, in terms of the phase rule, the simple system involved is $NaCl$-Na_2SO_4-H_2O and it is complicated only by the possible existence of the hydrates of sodium sulphate. Of these, the only one of any consequence is the decahydrate, Na_2SO_4, $10H_2O$.

The observed facts are explained as follows.

At the temperature of 37·5° C. at which the brine is drawn from the well, the solution is only rarely saturated with respect to the salts. It is usually unsaturated, though a study of the International Critical Tables will show that analysis No. 1 in Table IV practically corresponds with that of a saturated solution at the Na_2SO_4-NaCl transition point at 37·5° C., the hydrates of sodium sulphate being incapable of existence at that temperature.

The presence of sodium chloride has the effect of lowering the $Na_2SO_4, 10H_2O$—Na_2SO_4 transition point, the lowering being greater the higher the concentration of sodium chloride until a minimum transition point of 17·9° C. is reached, the transition point for the pure salt being 32·3° C. at atmospheric pressure.

In the circumstances described, $Na_2SO_4, 10H_2O$ is likely to separate at temperatures of 20° C. (68° F.) and lower which prevail in the cooler weather.

While the solubility curve of the decahydrate is fairly steep (considerable increase of solubility with rise in temperature), the anhydrous salt has a "negative" solubility curve. The separation of the decahydrate from the solution effects a concentration of the liquid phase with respect to sodium chloride by removing from the solution water amounting to 1·27 times the weight of the sodium sulphate itself. This may involve the partial co-precipitation of some sodium chloride but, as will be observed from the brine analyses (Table IV), the ratio of sodium sulphate to sodium chloride is such that the sodium chloride can still stand some increase in its concentration owing to the removal of $Na_2SO_4, 10H_2O$ before its saturation point is reached. The tendency of the sodium chloride to separate is to some extent counterbalanced by the removal of sodium sulphate, the presence of which lowers the solubility of sodium chloride. The separation of the sodium chloride will thus be relatively small but the temperature range over which Glauber's salt crystallises out will be somewhat increased. It is of course possible that some anhydrous sodium sulphate will crystallise out from the hot brine but this is of no consequence because it would ultimately change to the hydrated salt in contact with the aqueous solution at the lower temperature.

The brine, partly denuded of its sodium sulphate at night and early morning cold weather temperatures in the eliminator pans, can now be run into the (salt) crystallising pans for solar concentration at higher temperatures. This rise in temperature permits a greater concentration of sodium sulphate in solution before becoming saturated with respect to it and results in the separation of a crust of sodium chloride reasonably free from sulphate, because the solubility of sodium chloride does not vary much with temperature and so will speedily come to saturation on simultaneous evaporation and rise in temperature.

These relationships are shown in Fig. 1 which is only diagrammatic. The presence of small quantities of the carbonates of sodium does not materially affect the system and has been ignored.

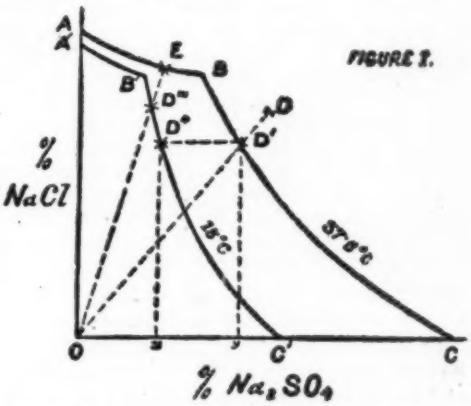

FIGURE 1.

A-B-C is the Na_2SO_4—NaCl solubility curve at 37·5° C. and A′-B′-C′ is the corresponding solubility curve for 15° C.

For convenience, sodium sulphate is plotted in terms of Na_2SO_4 though the solid phase for the lower curve (15° C.) is the decahydrate, $Na_2SO_4, 10H_2O$.

Suppose the brine drawn from the well has the (unsaturated) concentration D. This will correspond with a point D′ on the 37·5° C. saturation curve A-B-C. The solid phase in contact with this solution would be anhydrous sodium sulphate. Now imagine that this solution is cooled quickly to 15° C. Assuming that the concentration of the sodium chloride remains approximately the same, the corresponding point on the 15° C. curve would be D″ and a considerable amount of sodium sulphate, corresponding with the difference in the concentration, y-x

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on OC would have separated. But, at 15° C., this sodium sulphate which separates as decahydrate would actually have taken with it 1·27 times its weight of water and this would increase the concentration of the sodium chloride so that the composition of the liquid phase actually attained may be taken as D'''. On further concentration, Na_2SO_4, $10H_2O$ could separate until point B' is attained but only cooling takes place in the eliminator pans and not solar evaporation. At D''' therefore the brine is run off from the deposited Na_2SO_4, $10H_2O$ into the crystallising pans. Here the temperature rises and, on the Na_2SO_4-NaCl curve at 37·5°, the point attained (assuming no separation of solid phase to have taken place) will be E on the line joining O to D''' and produced to cut the curve AB.

The effect of this is that the solid phase in equilibrium with the solution, abruptly changes from Na_2SO_4, $10H_2O$ to NaCl. Now solar evaporation can proceed, the concentration of the liquid phase increasing along the composition curve EB with deposition of sodium chloride until composition B is attained. At this point Na_2SO_4 would also separate. Before this happens, either more brine must be added from the eliminators or the mother liquor must be run away so that contamination of the salt crust may be obviated.

Formation of Rohr

In the process as practised for many generations, much decahydrate obviously separated at the bottoms of the pans. The temperature subsequently rose beyond that at which Na_2SO_4, $10H_2O$ can exist and this salt lost water and became converted into anhydrous salt, assisted by the presence of the sodium chloride. The anhydrous sodium sulphate was left at the bottom of the pan and the sodium chloride which may have been deposited with the Glauber's salt passed into solution and diffused into the supernatant brine eventually adding its quota to the salt crust. The finely divided sodium sulphate slowly changed into the larger crystals obtained on excavation at a later stage. This process continues adding its quota to the bed annually, and the high percentage of sodium sulphate in the rohr, contaminated by wind-borne dust and sand, is accounted for on a scientific basis.

Papri

After crystallisation is over and the salt removed, the residual mother liquor is left in the pans to dry out and is recovered as "pan scale" or "papri", *vide* Table I.

Theoretically, the proportion of sodium chloride and sulphate in "papri" should correspond with that in the liquid phase at the transition point at the final temperature attained but, owing to the conditions including variable temperatures under which the drying out occurs, such a theoretical composition for papri cannot be expected and the widely differing compositions recorded are not anomalous.

1. *Records of the Geological Survey of India* (in the press). 2. J. B. Auden, B C. Gupta, P. C. Roy and Mehdi Hussain, *Rec. Geol. Surv. Ind.*, 1942, **77**, 36; 42.

OBITUARY

Prof. Richard Willstatter

READERS of *Current Science* will note with regret the death of Prof. Willstatter, one of the great masters of organic chemistry, on August 3, 1942, in Switzerland, a few days before his seventieth birthday, and three years after narrowly escaping a concentration camp when he was at Munich.

Starting with his brilliant work on alkaloids, he passed on to a variety of problems on catalysis, etc., and thence to intensive studies of natural colouring matters, principally chlorophyll, carotenes, and anthocyanins. The last phase of his work was another series of intensive investigations on the isolation, reactions and constitutions of enzymes, carried out with a brilliant band of collaborators. Willstatter was the first to develop the technique of selective adsorption in the preparation and separation enzymes. He was awarded the Nobel Prize in 1920.

EMBRYOLOGY OF ORCHIDACEÆ

BY

B. G. L. SWAMY

ORCHIDACEÆ comprising 450 genera and 7,500 species constitute a specialised group among angiosperms. In spite of their complex life-cycle only about 175 species (included under 75 genera) seem to have received the attention of morphologists, since the publication of the first available paper on the embryology of *Orchis* by Muller (1847). In the present article the author proposes to give a brief review of the scattered information on the embryological aspects of orchidaceous members.

Microsporogenesis and Male Gamete

Our knowledge concerning the microsporogenesis and the development of the male gametes is scanty and confined to the study of a few plants, and does not explain the organogeny of stamens, differentiation of parietal layers, tapetum, etc.

With the exception of *Paphiopedilum*, *Selenipedium* and *Cypripedium* most of the forms studied show only simultaneous divisions in the pollen mother-cell. In the three above-mentioned forms successive type has been noticed. In *Epidendrum raniferum* Hoffmann first suspected a successive type of development; but later confirmed it as a simultaneous type.

Details of the division of the uninucleate microspore into the tube and generative cells are incompletely understood. Recently investigations on the microsporogenesis of *Cymbidium* (Swamy, 1941) and *Eulophea* (Swamy, in press) have clarified many doubtful points. The nucleus of the microspore divides into an inner tube cell and an outer lenticular generative cell and a definite wall is laid down between them. After a time the separating wall disappears and gradually the plasma of the vegetative cell engulfs the tube nucleus which is surrounded by a small quantity of cytoplasm; ultimately the tube nucleus becomes spherical with a characteristic clear space around and comes to lie within the plasma of the vegetative cell. Such a type of "movement of the generative cell", as it is termed, has been reported in very few plants and it would be of great interest to discover if similar cases occur in other members of this family.

The mature pollinia of certain terrestrial orchids as *Orchis, Calanthe, Neottia, Calopogon*, etc., are in the form of small aggregates known as "massulæ" in contrast to almost all epiphytic forms where the entire pollen is massed up in the form of pollinia.

In most of the species the pollen is two-nucleate at the time of pollination. In *Cymbidium, Eulophea* and *Calopogon pulchellus* (Pace, 1909) the individual microspores of the quartet do not get separated, and germinate *in situ*. It is only in certain species of *Cypripedium* that they are seen to round off individually. The generative nucleus divides in the pollen tube into two male nuclei. The tube nucleus in *Cymbidium bicolor* exhibits a remarkable behaviour in that it elongates in the tube nearly ten times its original length before degenerating.

Zeuxine sulcata (Seshagiriah, 1941) exhibits some interesting peculiarities during the microspore formation. The "second mitotic division seems to be suppressed; hence 'dyads' of microspores are formed". These divide into vegetative and generative nuclei but such pollinia are not functional. In some pollinia the author reports the formation of abnormal spindles during the heterotypic nuclear division as a result of which supernumerary nuclei are formed.

Female Gametangium

The primary archesporium is subepidermal and single-celled, which directly functions as the megaspore mother-cell. Formation of the parietal layers is unknown in the family. Differentiation of two megaspore mother-cells which are either superposed or placed side by side, have been noticed occasionally in *Calopogon pulchellus* and species of *Cyprepedium* and in stray cases in *Gastrodia elata*. In *Calopogon pulchellus* some of the twin mother-cells were provided with individual covering of the nucellar epidermis. In *Oncidium prætextum* (Afzelius, 1916) the terminal epidermal cell of the archesporium has the appearance of the embryo-sac mother-cell.

In *Gastrodia elata* the embryo-sac is organised even before pollination. In many terrestrial orchids, however, especially, the

group-Habenarieæ, the ovaries show only the archesporial initials at the time of pollination; and their further development is dependent upon pollination. In some of the epiphytic orchids (*Cymbidium, Dendrobium, Cottonia, Vanda,* etc.), the archesporial cell is differentiated in the nucellus only after pollination.*

TABLE I

Showing the Orchids that exhibit the Allium and Adoxa types of development of Embryo-Sacs

Plant	Author	Remarks
Allium-type		
Achroanthes monophyllus	Stenar (1927)	
Cymbidium bicolor	Swamy (1942)	
Cypripedium spectabile		
C. parviflorum	Pace (1907).	
C. pubescens		
C. candidum		
Epipactis latifolia	Vermoessen (1911)	Only sometimes
E. pubescens	Brown and Sharp (1911)	Only sometimes
Gyrostachys cernua	Pace (1914)	Only sometimes
G. gracilis		
Neottia nidus avis	Modilewski	
Orchis sambucinia	Afzelius (1916)	Very rarely
Oncidium pretextum		
Paphiopedilum insigne	" "	
P. Leeanum		
P. spicerium		
P. barbatum	Francini (1930)	
P. villosum		
P. venustum		
Adoxa-type		
Bletia shepherdi	Sharp (1912)	Very occasionally
Epidendrum variegatum		
Epipactis pubescens	Brown and Sharp (1911)	Occasionally
Epipogon nutans	Swamy (unpublished)	
Gyrostachys cernua	Pace (1914)	Sometimes
G. gracilis		

In *Cymbidium bicolor* female archesporium is differentiated 3-4 days after pollination; in *Eulophea epidendræa* in about a week's time and in certain species of *Vanda* after more than ten days. In *Dendrobium anosum* the megaspore mother-cell was observed to be in division 76 days after pollination.

FEMALE GAMETOPHYTE

Monosporic eight-nucleate Normal-Type is the predominant course of development of the embryo-sac. Orchids showing other types of development are listed in Table I. *Epipactis pubescens* and two species of *Gyrostachys* are very variable, showing both Bisporic and Tetrasporic types of development. This variability in *Epipactis pubescens*, "may be due", according to the authors (Brown and Sharp, 1911), "however, to some condition such as nutrition, which is external to the megaspores, and is probably not due to potentialities inherent in the various megaspore nuclei; ..... The most reasonable conclusion would seem to be that different courses of development are due to conditions external to the nuclei, and that the fate of the nucleus will depend on its position". Sharp (1912) who reports Adoxa type as of occasional occurrence in *Epidendrum* and *Bletia* also lays much stress on the position of the spindles at the first two divisions, as the determining factor in influencing the further course of development and his conclusion is in accordance with the one for *Epipactis*.

Among the orchids investigated, the megaspores of the linear tetrad show a difference in their individual sizes soon after their formation, the three micropylar ones being very much smaller than the chalazal one. The upper cell of the dyad in many instances remains without any further development. The chalazal megaspore by further development forms the mature embryo-sac. It may be mentioned here that Chodat (1913) in *Ophrys apifera* and *O. botteroni* finds sometimes that the two lowermost megaspores resolve into embryo-sacs.

Differences in the number of antipodals are of common occurrence, and are often exhibited in different ovules of one and the same ovary. The retardation or even the suppression of nuclear divisions at the antipodal end is often responsible for the development of 5-, 6- or 7-nucleate embryo-sacs. Fusion of the daughter nuclei following division of the antipodals at the chalazal

* Recent investigations have revealed that for the development of the female gametophyte, the transference of actual pollen on to the stigmatic surface is not necessary in certain species of orchids to initiate the development of the magasporanium but a mere application of the pollen extract in any suitable solvent on to the stigma does not only induce the enlargement of the gynostegium but also initiate the development of ovules and ovary. But it is obvious that no fertilisation takes place due to the absence of the male element. According to Laibach (1932) the orchid-pollen-substance is capable of streaching *Avena coleoptiles* and he is of the opinion that this active substance is related to the other growth-promoting auxins.

end which has been observed in *Gastrodia elata* (Kusano, 1915), *Cypripedium guttatum* (Prosonia, 1930), etc., ultimately results in an embryo-sac with less than eight nuclei According to Sharp (1912) the presence of 6-nucleate embryo-sacs in certain of the species investigated by him "seem to show a tendency towards a further reduction of the vegetative portion of the gametophyte".

The genus *Cypripedium* has raised a keen controversy in the orchid embryology. Pace (1907) studied four species of this genus in which she first described the "*Cypripedium*-type". According to her the lower dyad cell divides twice resulting in a pair of nuclei at each end of the embryo-sac. The upper pair constitutes the synergids; the lower forms the egg and the single polar nucleus. During the time of fertilisation one of the synergid nuclei descends down and takes part in the triple fusion with the second male nucleus. This was subjected to severe criticism by Rutgers (1923), who demanded a confirmation of Pace's work. Prosonia (1930) investigated *Cypripedium guttatum* and found the development to be very much similar to the Allium-type but with certain amount of reduction at the chalazal end of the embryo-sac, as a result of which 5- or 6-nucleate condition of the mature embryo-sacs arose. Francini's (1930) investigations on other species of *Cypripedium* corroborate Prosonia's findings. Carlson (1940) has re-investigated *Cypripedium parviflorum*. Unfortunately her work has not so far resulted in any substantial contribution to the megasporogenesis but she hopes to study the same in light of the previous work on the genius. According to her the mature embryo-sacs in the species studied by her contains 8 nuclei though "more evidence is required to settle this point".

In this connection the type of development in *Gastrodia elata* (Kusano, 1915) may also be considered. In this plant the chalazal megaspore of the tetrad develops into a mature embryo-sac of 4 nuclei; two synergids, one egg and one polar, similar in organisation to the one described by Pace for *Cyprepedium*. The author (Kusano, 1915) also found in *Gastrodia elata* at the time of fertilisation one synergid leaving its position and taking part in triple fusion. "Perhaps influenced by the work of Pace", as Schnarf remarks, Kusano reports the above condition; but in the opinion of the present author a reinvestigation of the form might reveal only a normal type of development, probably with reduced antipodal nuclei.

Fertilization and Endosperm

The time taken by the pollen tube from the time of pollination to actual entry into the embryo-sac is highly variable. The shortest period so far recorded is four days for *Gastrodia elata* (Kusano) and the longest in the case of *Vanda suavis* as observed by Guignard. Fertilization is strictly porogamous; double fertilization has been observed in most of the species investigated.

In the majority of forms examined, the development of endosperm proceeds upto the stage of triple fusion. Even this might be incomplete due to the fact that the polars remain just apposed and do not fuse.

The division of the secondary endosperm nucleus up to 2-3 divisions has been recorded so far only in five forms, *viz.*,

Cypripedium spectabile, *C. parviflorum*, *C. pubescens* } (Pace, 1907).

Paphiopedilum insigne, *Chœmæorchis alpina* } (Afzelius, 1916).

Sharp (1912) referring to the work of Pace on *Calopogon pulchellus* states that this plant is the only known case of endosperm formation among orchids. But a careful perusal of Pace's paper by the writer, however, revealed no such statement made by Pace herself about the endosperm. In fact only its stages upto double fertilisation have been described by her. In 1900 Nawaschin attributed the lack of endosperm to the failure of complete fusion of the polars or the second male nucleus. But Strasburger in the same year showed in several European orchids, that in spite of the complete fusion of the polar nuclei and the second male nucleus, endosperm did not develop. How it is that in this particular family the endosperm tissue is not seen in evidence, it is still difficult to determine.

Embryo

A most pronounced feature of the family is the undifferentiated embryo in the mature seed. The highest differentiation so far recorded is in *Sobralia macrantha* (Treub, 1879) where a clear differentiation into cotyledon and hypocotyl region is

observed and *Platyclinis* (Rendle, 1930) with a "terminal green cotyledon".

The zygote divides as a rule by a transverse wall; it is only in *Cymbidium bicolor* that the first wall may be sometimes laid down either vertically or obliquely to the long axis of the embryo-sac. A proembryo of a chain of three cells is formed, the terminal cell of which undergoes further divisions to form the actual embryonal mass. The basal cell usually develops into a suspensor whose shape and structure is most variable.

Complete lack of any suspensor has been noticed in *Epipactis pulstris, Listera ovata* (Fig. 2), *Cypripelium reginæ* and *Zeuxine sulcata*. In *Spathoglottis plicata* the uppermost cell of the proembryo towards the micropyle enlarges and sometimes grows out of the microplye; a similar case is reported by Treub (1879) in *Goodyera discolor* (Fig. 1). Very frequently in genera like *Orchis, Gymnadenia, Phajus*, etc., the suspensor consists of a single row of cells. In *Epidendrum ciliare* (Fig. 8) it is very long consisting of several tiers of cells, which are superposed. In several *Habenaria* species (Fig. 9) noticed by the writer (unpublished), the filamentous row of the suspensor cells grows out of the micropyle; and the terminal cell of the suspensor embeds itself in the placental tissue and acts like an aggressive haustorium. The suspensor in a number of cases sometimes branches profusely as in *Serapias lingua* (Fig. 7). In certain species of *Vanda*, the basal cell undergoes four vertical divisions resulting in the formation of eight cells which grow towards the chalaza and engulf the growing embryo (Fig. 5). In *Cymbidium* and *Eulophea* the succeeding few divisions of the zygote after its first transverse division are most irregular; one of the cells situated at the chalaza develops a filamentous row of cells, the terminal two or three cells towards the free end contributing to the actual embryo; the irregularly divided cells grow out and elongate in all directions inside the seed coat but do not reach any nutritive zones (Fig. 4). In *Stanhopea* also the development seems to be similar with some variations. In *Phalænopsis grandiflora* (Fig. 3) the basal cell is divided by longitudinal walls to form a quadrant and each cell of the quadrant develops conspicuous copious tubular outgrowths which grow towards micropyle and chalaza.

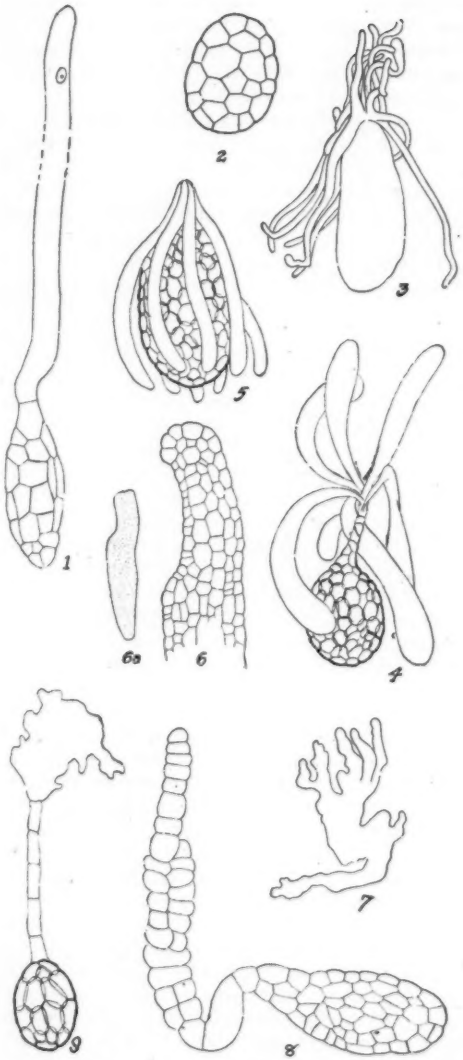

FIG. 1 Embryo of *Goodyera discolor*, showing the unicellular tubular suspensor, × 120. FIG. 2. Embryo of *Listera ovata* which has no suspensor, × 120. FIG. 3. Embryo of *Phalænopsis grandiflora*, showing the profusely branched suspensor, × 125. FIG. 4. Embryo of *Eulophea epidendræa*, × 100. FIG. 5. Embryo of *Vanda spathulata*, × 120. FIG. 6. Terminal "cotyledonary" region of the embryo of *Sobralia macrantha*, × 120. FIG. 6a. Outline of the entire embryonal mass of *Sobralia macrantha*, × 45. FIG. 7. Terminal haustorial cell of the suspensor of the embryo of *Serapias Lingua*, × 85. FIG. 8. Embryo of *Epidendrum ciliare*, × 200. FIG. 9. Embryo of *Habenaria rariflora*, × 120. FIGS. 1, 2, 3, 6, 6a, 7 and 8, after Treub, 1879.

The function of such elaborately organised suspensor organ is not quite clear. Treub (1879) attributed the function of absorption of nutritive substances to this organ. In some instances, no doubt, they are definitely concerned with the absorption of nutrilites. As against this, in many cases their function as a haustorium has to be doubted. For instance, in many plants, they do not reach any nutritive tissues or possess rich cell contents. The nuclei in these, in fact, degenerate. Such being the case, we might have to modify the statement made by Coulter and Chamberlain (1903) (cited by Kusano, 1915) that "every suspensor is an Haustorium".

Polyembryony and Other Phenomena

Schnarf (1931) has listed a number of species in Orchidaceæ that exhibit more than one embryo in a single seed. In many cases the exact origin of the additional embryos has not been traced. In *Gastrodia elata* two embryo-sacs in the same ovule often develop to maturity, separate pollen tubes enter each of these and by further development after fertilisation normal diploid embryos are formed in one ovule. In the same plant, according to Kusano (1915), "at delayed fertilisation of the ovule the synergid tends to develop into an adventitious embryo. In this case fusion between the male and synergid nuclei is highly probable", in case of which the resulting embryo will be diploid (if Kusano's surmise is reliable), and "under a special condition the haploid egg may undergo the nuclear division leading to the generative parthenogenesis, but no cell division is ascertained", in which case the ensuing embryo will be haploid.

The occurrence and origin of haploid embryos in addition to nucellar ones has recently been recorded in *Zeuxine sulcata*. In this plant the megaspore mother-cell after the usual reduction divisions forms a lienar row of four megaspores; these upon undergoing anticlinal and periclinal divisions give rise to the haploid embryo.

Apomictic development associated with polyembryony (the origin of all the embryos being similar) is recorded in *Nigretella nigra* (Afzelius, 1928, 1932). In this plant the sexual development of the female gametophyte continues only till the four-nucleate stage. Even though the development of the pollinia is quite normal and functional fertilisation is not accomplished and all the embryos that arise are from the nucellar epidermis that caps the female archesporium. A very similar type has been described in *Zeuxine sulcata* but the pollen here is completely sterile.

In *Cymbidium* and *Eulophea* cleavage type of polyembryony is recorded and the resulting embryos are monozygotic. In *Cymbidium bicolor* sometimes the first wall laid down in the zygote will be vertical and under such circumstances in some cases the two cells develop independently and produce two embryos. In *Eulophea epidendracea* (Swamy, in press) it is seen that any region of sexually produced embryo proliferates or buds off additional embryos.

Without entering into any discussion as to the cause of polyembryony, it may be stated that a large number of morphologists hold the view that sudden environmental changes might play an important part. Ernst (1918) on the other hand assumes that hybridisation as being the primary cause and nutritional disturbances as one of the probable causes in inducing polyembryony. The cause in *Zeuxine sulcata* "seems that this nutrative disturbance, just prior to the reproductory phase, may set up causes which bring about the phenomenon seen in" this plant, and the author (Seshagiriah, 1941) opines that "Nekrohormones" which are believed to bring about adventitious embryos in *Œnothera* may act in this particular case also.

(*Note.*—Only very important references are given here due to the scarcity of space.)

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LETTERS TO THE EDITOR

	Page
Note on a Particular Test for Convergence. By V. S. Ananthachar	18
The Open-Arc Method of Exciting the Balmer Series. By A. S. Ganesan	18
Gel-Formation by Mutual Interaction of Oppositely Charged Sols. By Mata Prasad and S. D. Mehta	19
Parachors and Molecular Diameters. By M. S. Telang	19
Vitamins, Minerals, Carbohydrates and Proteins in Fruits—II. By N. D. Rege and S. C. Devadatta	20
A Chromatographic Adsorption Method for the Estimation of the Provitamin A Content of Foodstuffs. By G. B. Ramasarma, D. N. Hakim and S. D. Rao	21
The Effect of Nutrition and Climate on Rat Leprosy. By S. Mahdihassan	22
Estrogen Therapy of the Indian Cress Oil. By M. B. Sahasrabuddhe and N. N. De	23
A Search for Porphyroxine in Bengal Opium. By S. Rajagopalan	24
Protogeny in Uganda Spontaneum. By N. L. Dutt and M. K. Krishnaswamy	24
On Akinete Formation in Zygnema terrestris *Randh.* By M. S. Randhawa	26
Riccia gangetica *Ahmad.* By R. S. Chopra	27

NOTE ON A PARTICULAR TEST FOR CONVERGENCE

If $\sum^{\infty} a_n$ is a series of positive terms, and if

$$\frac{a_n}{a_{n+1}} = 1 + \frac{f'(n)}{f(n)} + \frac{\rho_n}{f(n)}$$

where $f(x)$ is a continuous function such that $f''(x)$ tends to zero as x tends to infinity, then the series is convergent if $\overline{lim}\ \rho_n > 0$, and divergent if $\overline{lim}\ \rho_n < 0$.

In the proof of this result, Bromwich[1] works out and uses a peculiar form of the second mean value theorem, *viz.*,

$$f(n+1) = f(n) + f'(n) + \int_0^1 dx \int_0^x f''(n+t)\, dt.$$

But there is no need for this special form, and the proof will be rendered easier by using the familiar form, *viz.*,

$$f(n+1) = f(n) + f'(n) + \tfrac{1}{2} f''(n+\theta), 0<\theta<1.$$

V. S. Ananthachar.

Mysore,
December 12, 1942.

1. Bromwich, *Infinite Series*, 1926, p. 39.

THE OPEN-ARC METHOD OF EXCITING THE BALMER SERIES

When a steady stream of hydrogen is passed into a copper arc the Balmer series of lines is excited. The series is also obtained if instead of hydrogen, a stream of coal-gas or steam is used. In fact, with steam more lines of the series appear and their intensity is even greater than with hydrogen. In all these cases, however, the lines are very broad compared to what are obtained with an ordinary discharge tube. A series of experiments with different metallic arcs run at various current strengths brought out two significant facts: (*i*) The Balmer series is excited only with the copper arc and no trace of the series is to be observed with iron, zinc, aluminium or carbon arcs. (*ii*) Along with the hydrogen lines, the OH Bands $^2\Sigma \rightleftharpoons {}^2\Pi$ at λλ 3064 and 2811, also appear and as regards occurrence and intensity these bands and the Balmer series of lines go *pari passu*.

That the excitation of the hydrogen lines is not a pure temperature phenomenon becomes obvious. Two explanations suggest themselves. First, in the case of the arcs where the hydrogen lines are not excited, the hydrogen supplied is used up in reducing the oxides of the electrodes formed. With copper arc, copper being less easily oxidised, a free supply of hydrogen becomes available for excitation. Second, and what seems more plausible, the excitation of the hydrogen atom is due to some collision processes taking place in the copper arc.

In the case of copper it is well known that the electronic configuration $3d^{10}\ 4s$, gives the series of normal doublet levels, while the configuration $3d^9\ 4s^2$ gives a system of inverted doublet and quartet levels. Some of these latter levels lie in the continuum above the limit of the level $3d^{10}\ {}^1S_0$. If an excited copper atom in one of these levels makes an inelastic collision with a hydrogen atom and comes down to the level $^1S_0$, the energy so liberated may be sufficient to raise the hydrogen atom from the second to the higher orbits thus giving rise to the Balmer series. Alternatively, a collision between a copper atom

in the $3d^9$ 4*s* level and a hydrogen atom may result in bringing the copper atom to the $3d^{10}$ level and exciting the hydrogen atom to higher levels.

It is also observed that the injection of steam or hydrogen greatly modifies the intensity of a number of copper lines, especially in the region below λ 3000. A detailed analysis of the lines which are so modified will give a clue to the nature of the collision processes involved in the arc.

A. S. GANESAN.

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Nagpur,
January 1, 1943.

GEL-FORMATION BY MUTUAL INTERACTION OF OPPOSITELY CHARGED SOLS

A STUDY of the literature reveals that most of the inorganic gels have been prepared by the following two methods:

(*i*) Metathetical reaction: In this method solutions of definite concentrations of substances which on reacting give rise to the gel-forming substance, are mixed in suitable proportions. The resultant mixture is clear in some cases (silicic acid)[1] while in others[2,3] a precipitate is obtained which disappears on slight or vigorous shaking.

(*ii*) Addition of an electrolyte to a sol: In this case certain electrolytes of suitable concentration are added to a fairly concentrated sol of the gel-forming substance, dialysed to a certain extent.[4]

However, other methods, such as the action of α-, β- and X-rays on a sol (Fernau and Pauli),[5] addition of non-electrolytes to a sol (Freundlich),[6] dilution of a true solution of a gel-forming substance (Prasad and Desai),[3] have been used in particular cases.

The authors have discovered that transparent or translucent gels are formed when oppositely charged sols of suitable concentrations, dialysed and undialysed, are mixed together in proper proportions. So far as the authors are aware it has always been observed that mutual coagulation takes place when oppositely charged sols are mixed together in proper proportions. The formation of gels by mixing oppositely charged sols seems to be a new observation. The first observations were made on mixing the sol of nickel hydroxide (negatively charged) with sols of ferric and aluminium hydroxide (positively charged). The nickel hydroxide sol was prepared by shaking with distilled water the gel obtained by the addition of NaOH solution to a saturated solution of nickel hydroxide in tartaric acid and its colloidal content corresponded to 3·01 g. of nickel per litre of the sol. The ferric and aluminium hydroxide sols were prepared by the hydrolysis of ferric chloride and aluminium acetate, respectively, and their colloidal contents were found to correspond to 3·05 g. of Fe_2O_3 and 2·34 g. of Al_2O_3, respectively, per litre of the sols. Gels were obtained when 5 c.c. of the nickel hydroxide sol were mixed with the following volumes of the ferric hydroxide sol dialysed to different extent.

TABLE I

Days of dialysis	Volume limits
0	1·30—1·55 c.c.
1	1·70 - 2·40 ,,
2	2·35—3·05 ,,
3	3·50—4·20 ,,
4	5·30 - 5·80 ,,
5	5·25—6·75 ,,

Gels have now been obtained on mixing (*i*) the sol of aluminium hydroxide (+ve) with sols of manganese dioxide (−ve), antimony sulphide (−ve) and silicic acid (−ve), and (*ii*) the sols of ferric hydroxide (−ve) and silicic acid (+ve).

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Chemical Laboratories,
Royal Institute of Science,
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December 29, 1942.

1. Prasad and Hattiangadi, *J. Indian Chem. Soc.*, 1929, **6**, 653. 2. Prakash and Dhar, *Ibid.*, 1929, **6**, 587; 1930, **7**, 367. 3. Prasad and Desai, *J. Univ. Bom.*, 1938, **7**, 132. 4. Freundlich and Leonhardt, *Koll. Beih.*, 1915, **7**, 195; Weiser, *J. Phys. Chem.*, 1922, **26**, 418, 681; Schleck and Szegvari, *Koll. Z.*, 1932, **60**, 1847; Prakash, *Koll. Z.*, 1932 **60**, 184; *J. Indian Chem. Soc.* 1932, **9**, 193. 5. Fernau and Pauli, *Koll. Z.*, 1917, **20**, 20. 6. Freundlich, *Ibid.*, 1928, **45**, 348.

PARACHORS AND MOLECULAR DIAMETERS

THE mean value of $\frac{[P]}{V_0}$ is 2·873,[1] where [P] is the parachor and V_0 is the zero volume at absolute zero. At absolute zero, parachor can be written as

$$[P] = \frac{M}{D_0\ d_0}\gamma_0^{1/4} = V_0\,\gamma_0^{1/4},$$

all the terms involved having their usual significance.

So, $\frac{[P]}{V_0} = \gamma_0^{1/4} = 2{\cdot}873$. Hence, $\gamma_0 = 68{\cdot}2$ for a majority of substances. However, it has been observed that γ_0 varies between 60 and 80 for many organic substances.[2] But, for purposes to be described below, the value of γ_0 may be taken as a constant for all normal substances.

The following equation[3] gives a relation between density and temperature;

$$D_0 = \frac{D - d}{(1 - T_r)^{3/10}}.$$

Since $V_0 = \frac{[P]}{2{\cdot}873} = \frac{M}{D_0}$, $D_0 = \frac{M.\ 2{\cdot}873}{[P]}$.

Temp.	Benzene		Chlorobenzene		Carbon tetrachloride	
	σ_v	σ_p	σ_v	σ_p	σ_v	σ_p
0° C. ..	5·87 × 10^{-8} cm.	5·89 × 10^{-8} cm.	6·15 × 10^{-8} cm.	6·17 × 10^{-8} cm.	6·03 × 10^{-8} cm.	6·03 × 10^{-8} cm.
40 ..	5·97	5·97	6·23	6·24	6·13	6·12
80 ..	6·08	6·08	6·32	6·33	6·25	6·23
120 ..	6·21	6·21	6·42	6·42	6·39	6·37
160 ..	6·38	6·37	6·53	6·54	6·57	6·55
200 ..	6·63	6·62	6·68	6·69	6·85	6·81

Hence, neglecting d which is usually small and rewriting,

$$[P] \cdot \frac{D}{M} = 2{\cdot}873\,(1 - T_r)^{3/10} \text{ or}$$

$$[P]/V = 2{\cdot}873\,(1 - T_r)^{3/10},$$

where V is the molecular volume.

This relation between molecular volume and parachor is useful in calculating molecular diameters of substances at any temperature. The above expression gives

$$V = \frac{[P]}{2{\cdot}873\,(1 - T_r)^{3/10}}.$$

If molecules are assumed to be elastic spheres closely packed together, it is calculated that

$$\sigma = 1{\cdot}326 \times 10^{-8} \sqrt[3]{V} \text{ cm.}, \qquad \text{(i)}$$

where σ is the molecular diameter. Substituting for V in (i),

$$\sigma = 1{\cdot}326 \times 10^{-8} \sqrt[3]{\frac{[P]}{2{\cdot}873\,(1 - T_r)^{1/10}}} \text{ cm.}$$

$$= 0{\cdot}933 \times 10^{-8}\, \frac{[P]^{1/3}}{(1 - T_r)^{1/10}} \text{ cm.} \qquad \text{(ii)}$$

It may be remarked that if γ_0 varies between 60 and 80 (see reference 2), the values of γ_0 under extreme cases, may be taken as $68{\cdot}2 \pm 12$. Since the value of γ_0 employed in deducing equation (ii) is the reciprocal of the 12th root, the maximum possible error in calculating the value of σ would be 1·5%.

In the above table, the values of molecular diameters for three substances at six different temperatures are calculated by both the equations (i) and (ii). The values of σ_v are obtained by equation (i), from V = M/D where M is the molecular weight and D is the density of the liquid. Density data at various temperatures are taken from Sugden's paper 4; σ_p is calculated by equation (ii).

The good agreement between the two sets of values of molecular diameters of non-associated liquids is a proof regarding the validity of the equation (ii) proposed for calculating molecular diameters in normal liquids, over a wide range of temperatures. Strictly speaking, the values of σ represent the upper limits of the average distances between the centres of adjacent molecules in the liquid state.

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December 12, 1942.

1. Sugden, *J. Chem. Soc.*, 1927, p. 1783. 2. Sugden, *Ibid.*, 1784. 3. Sugden, *Ibid.*, 1781. 4. Sugden, *Ibid.*, 1782.

VITAMINS, MINERALS, CARBOHYDRATES AND PROTEINS IN FRUITS—II

The amount of minerals such as calcium and phosphorus and of vitamins that take part in human metabolism are not large. Therefore one may look for a supply of these essentials in fruits though in small quantities, but in the *soluble form*. In the investigation presented here we have analysed ten fruits for protein, sugars, calcium, phosphorus, vitamin B, and in some, vitamin C. Water and trichloracetic acid extracts and ash of the fruits were examined for soluble and insoluble constituents.

Detailed estimations of carbohydrates are published elsewhere.[1] Brigg's colorimetric method for phosphorus, McCrudden's volumetric method for calcium and Kjeldhal's method for protein were adopted. For vitamins C and B_1 the water extract of fruit was taken. For the estimation of vitamin C dichlorophenol-indophenol method[2] was adopted. In the case of vitamin B_1 the quantity of water used for extraction was kept large. The extract was clarified with the minimum quantity of basic lead acetate and sulphuric acid and was then treated with norite. Pure vitamin was retained by norite which was later on released by acidulated water and estimated by using thiochrome method by H. Tauber.[3] Details will be published elsewhere.

All fruits contain sugars and some have starch in addition. Sugars present are mainly glucose and fructose. The concentration of phosphorus from water and acid extracts and from ash is same and is in ortho condition. Same is true with calcium except in sapota

Analysis of 100 gm. of Fruit

Common Name	Botanical Name	Proteins gm.	Sugars gm.	Phosphorus gm.	Calcium gm.	Vitamin B_1 mgm.	Vitan in C mgm.
1. Chiku	*Sapota zapolilla*	0·938	9·21	0·012	0·019	0·078	
2. Orange	*Citrus aurantium*	0·628	8·31	0·013	0·013	0·108	53·5
3. Figs	*Ficus carica*	1·114	9·07	0·024	0·052	0·042	
4. Guava	*Psidium guyava*	1·39	9·44	0·028	0·109	0·045	
5. Plantain—Velchi ..	*Musa sapientum*	1·15	18·33	0·032	0·003	0·138	0·82
6. Plantain—Green Skin	,, ,,	1·07	17·83	0·029	0·003	0·132	
7. Plantain—Rasbali .	,, ,,	1·11	18·07	0·027	0·006	0·126	
8. Apple Red ..	*Pyrus malas*	0·25	10·48	0·022	0·007	0·099	1·08
9. Apple—Yellow green	,, ,,	0·242	10·50	0·022	0·007	0·090	1·24
10. Grapes—Yellow ..	*Vitis vinefera*	0·54	14·69	0·016	0·24	0·036	

which has 30 per cent. water-insoluble (acid-soluble) when analysed with skin on, the rest being water-soluble. The amounts of vitamins present are fairly high especially B_1 in plantain, apple and sapota.

N. D. Rege.
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Wilson College,
Bombay,
November 26, 1942.

1. Rege and Devadatta, *J. Univ. Bomb.*, 1941 **10, 3,** B, 74. 2. *Nature*, 1933, **15,** 132. 3. Tauber, H., *Mikrochem. Acta*, 1938, 108.

A CHROMATOGRAPHIC ADSORPTION METHOD FOR THE ESTIMATION OF THE PROVITAMIN A CONTENT OF FOODSTUFFS

Recent work[1] from this laboratory has shown that the petroleum ether-methyl alcohol phase partition for the separation of carotene from xanthophyll is unsatisfactory because some coloured but biologically inactive degradation products also remain in the epiphasic layer and are, therefore, estimated as carotene. Errors due to the presence of such non-carotene pigments have been found to be rather high in the case of stored foodstuffs like cereals, pulses and condiments. Further, the inactive isomer, lycopene, is likely to be estimated as carotene while no account is taken of the fact that β-carotene is biologically twice as potent as any of the other pro-vitamins A. A correct estimation of the vitamin A activity of any vegetable material can be made only by determining the amounts of the different pro-vitamins present and employing the formula: Vitamin A activity in International Units =

$$\frac{\mu g \text{ of } \beta\text{-carotene}}{0{\cdot}6} + \frac{\mu g \text{ of other provitamins}}{1{\cdot}2}.$$

Chromatographic adsorption which offers the only means of separating these pigment mixtures has not been used as a routine method of estimation since the pigments may be lost to the extent of 10 to 20 per cent. due to incomplete elution from the adsorbent. However, by the application of the chromatographic adsorption in two stages and by a choice of suitable adsorbents, it has been possible to estimate firstly, the total carotene (including lycopene, if present, but no artifacts) and then the relative proportions of the constituent pigments. After repeated trials with a number of substances, dicalcium phosphate prepared according to Moore[2] was found to be satisfactory for the first chromatography. Xanthophylls and artifacts are strongly adsorbed by it, while carotene and lycopene pass down practically unadsorbed. Cryptoxanthin is only weakly adsorbed and, therefore, it can be collected sepaartely by further developing the chromatogram. Recovery experiments with pure β-carotene solutions have shown that the losses are never more than 2 per cent. with a properly prepared adsorbent column.

The carotene solution thus obtained is concentrated to a small volume and chromatographed over a column of Brockmann's alumina. The bands are eluted separately and the different pigments identified and their concentrations determined. The eluates may account for a recovery of about 85 per cent. only but since the three common hydrocarbon pigments—β-carotene, α-carotene and lycopene—differ very slightly in their adsorbabilities, it may be reasonably assumed that the losses would be proportionate. Using this proportion the quantities of the individual pigments present in the original carotene extract (first chromatography) are calculated.

A number of foodstuffs have been assayed for their provitamin A content employing the extraction procedure described in an earlier paper[3] in conjunction with the adsorption technique described above. All the estimations were on petroleum ether (b.p. 60-75° C.) solutions, taking readings at three wavelengths (450, 470 and 480 $m\mu$) in a visual spectrophotometer and employing extinction coefficients derived from a sample of pure β-carotene isolated from Badami mango fruit.[4]

Provitamin A content in 100 grams of material

Name of the Material	Health Bulletin (1 μg = 1 I.U.)	By the authors			
		Phase partition method μg. "Carotene"	Chromatographic method μg. "Carotene"	Composition of the "Carotene" (per cent.)	Vitamin A activity in Int. Units (Calculated)
Papaya fruit ..	2020	—	1280	C 90; β-10	1170
Coriander seeds ..	1570	230	100	L 55; β-45	73
Dry chillies ..	576	11200	6230	β-71; α-26	8820
Gingelly seeds ..	100	21·0	12·0	—	<20
Whole wheat ..	108	21·0	(?) 6·0	—	<10
Horse gram ..	119	74	16	Mostly β-	27
Mace ..	—	3580	2150	L(?) 92; β-8	290
Fenugreek seeds ..	160	660	260	β-92; ? 8	420

L = lycopene; C = cryptoxanthin; α- = α-carotene; β- = β-carotene
? = doubtful identity.

A few typical results are presented in the above table. For the sake of comparison, values for the carotene content given in Health Bulletin No. 23 (Third Edition) of the Government of India, are also included in the table; these are mostly obtained from the work of De and co-workers.[5] The figures clearly show that, apart from varietal differences and individual variations, a large proportion of the pigment present in stored foodstuffs and estimated as carotene by the phase separation method may be actually of a non-carotene nature. Further, the results indicate the need for a thorough re-investigation of the common food materials employing these improved methods.

Finally, a word of caution is necessary with regard to the first chromatography. There are many variables in the experimental procedure —the adsorptive power and particle size of the dicalcium phosphate, size of the column and the method of packing, vacuum applied for packing and during the experiment, etc.,— and unless special care is taken, considerable errors may be introduced into the determinations. At the outset, all these experimental conditions should be standardised to give quantitative recoveries of carotene and the details strictly adhered to subsequently. It is further recommended that each lot of adsorbent be tested to give a proper performance before making use of it for estimations.

In the case of leafy vegetables and similar rich sources, saponification of the pigment extract may be omitted but it is essential in the case of poorer materials since the presence of more than 25 mg. of oil in the extract interferes with the adsorption of some of the non-carotene pigments while more than 150 mg. of oil is definitely objectionable.

Full details of the method and analytical data on the provitamin A content of a number of foodstuffs under investigation, will be published elsewhere.

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Bangalore,
January 8, 1943.

1. Ramasarma, G. B., and Hakim, D. N., *Nature*, 1942, **149**, 611; *Ann. Biochem. Exp. Med.*, 1942, **2**, 181. 2. Moore, L. A., *Ind. Eng. Chem., Anal. Ed.*, 1940, **12**, 726. 3. Ramasarma, G. B., *Ann. Biochem. Exp. Med.*, 1942, **2**, 103. 4. Ramasarma, G. B., Rao, S. D., and Hakim, D. N. (Unpublished data). 5. De, N. K. and coworkers, A number of papers in *Indian J. Med. Research*, 1935–38.

THE EFFECT OF NUTRITION AND CLIMATE ON RAT LEPROSY

Clinical experience of leprosy has given a universal impression all over the world that it is a "poverty disease". It means that more than infection predisposition is a more vital factor and this lies in some defective nutrition. To solve this mystery attempts have been made and are still being continued to trace the nutritive factor to some vitamin deficiency particularly to that of vitamin A. Apart from this, regional distribution of leprosy has been well recognised as an unsolved problem. There may be a village where leprosy incidence may be ten per hundred or even more whereas in the whole geographical province where food and race are not apparently different it may not be more than ten in a thousand of population.

Unfortunately no laboratory animal has data on the provitamin A content of a

leprosy so that no experiments could have been undertaken to show a connection between its nutritive and infective factors. But rats suffer from a leprosy of their own upon which again no experiments have been reported to show a nutritive basis of predisposition or a regional factor leading to infection.

About half a dozen rats were obtained through the kindness of Dr. Lowe in Calcutta which had been infected with rat leprosy over seven months previously. One of these rats was used for infecting a batch of white rats kept in the animal house of the Osmania Medical College in Hyderabad. The rats were given a very simple diet; Bengal gram soaked overnight in water and fresh lucern; of those two items they got as much as they could eat. Along with the rats some rabbits and Belgian hares were also kept and given the same diet. The food and the climate did not prove congenial at least to the rabbits, for within eighteen months these animals developed a very infectious skin disease and had to be destroyed on that account. The rats, on the contrary, did not show any sign of skin trouble.

Twenty rats were selected, all about a year in age. Ten of them got an emulsion of rat leprosy tumour where each drop was teaming with germs; of a total dose of one c.c., half a c.c. was injected intraperitoneally and the rest subcutaneously. Another ten rats got a total dose of half c.c. again injected intraperitoneally and subcutaneously. Of these twenty rats, six died within ten days and the rest that survived got one and all tumours on the skin at the site where they were injected subcutaneously after seven months. Internal organs were also affected whenever they were examined. This experiment gave results typical of rat leprosy and needs no further comment.

As I also work for some months at the Indian Institute of Scienee, Bangalore, I took two rats originally sent by Dr. Lowe and they were sacrificed to give an emulsion with which 14 rats were infected. Ten of them got a total dose of 1 c.c. injected, as in the case of Hyderabad batch of rats, in two places, intraperitoneally and subcutaneously and the rest, namely, four rats, got a total dose of only half a c.c. The actual operation of injection was done by my friend, Dr. Naidu, of the Serum Institute, and was carried out in his laboratory at Hebbal. After the animals were injected they were brought over to the Animal House of the Biochemical Department of the Indian Institute of Science, where they were kept on the well-known MacCarison diet, comprising of wheat flour, fat and salts. It is the diet used at the Nutrition Research Institute, Coonoor, and is rich in vitamins and has proved the best for breeding rats. Even after eighteen months the rats kept at Bangalore showed no sign of any disease and fortunately none had died. Subsequently they were used by other workers for a different experiment as though they had been perfectly healthy. It is very difficult to interpret this finding. The animals were infected from material that was microscopically controlled and found to be highly infective; the actual operation was carried out by an expert veterinary surgeon; and they were kept in an animal house of an all-India famous Institute.

Dr. De, the pharmacologist at the Indian Institute of Science, kindly infected another batch of rats and Prof. V. Subrahmanyan had been good enough to allow me to repeat the experiment. This experiment also gave similar results so that it is evident there is a great difference in the food and climate as effecting leprosy rats in Hyderabad and those kept at Bangalore. Judging from the health of the rabbits upon the same diet as given to the rats there is no doubt that the animals at Hyderabad were very badly off.

A preliminary report is a very dangerous one in so far as it appears exciting and even promising but has no value unless it is confirmed and it is here that the co-operation of others is required. I have taken all care to claim nothing which is not due to me and as the experiments take a long time to carry out it is advisable that others interested in leprosy might try to confirm or contradict the above finding. The findings above do not allow of any other interpretation than that mentioned above, so that if confirmed, would only bear out what has been believed but not proved so far, namely, that good food and favourable climate both acting together make man immune to leprosy.

The Osmania University had kindly sanctioned some funds for research on leprosy and I beg to thank the authorities for their kindness. It is hoped that these experiments would be extended.

S. MAHDIHASSAN.

Osmania Medical College,
Hyderabad (Dn.),
December 14, 1942.

ESTROGEN THERAPY OF THE INDIAN CRESS OIL

INDIAN *cress* (*Lepidium sativum* Linn.); a familiar shrub belonging to the N.O. cruciferæ, figures very prominently in the Indian materia medica. Among the various medicinal virtues ascribed to this seed, the chief are its galactagogue and enenagogue properties. In certain parts of India sweet balls prepared from these seeds are still used as a special tonic after delivery.

A detailed study of the pharmacological action of the active principles of the seed has been undertaken by us. The proximate analysis of the seed gives moisture 5·69 per cent., ash 5·7 per cent., crude protein 23·5 per cent., crude fat 15·91 per cent., P_2O_5 1·65 per cent., calcium 0·31 per cent., and sulphur 0·9 per cent.

The seed on steam distillation yielded a volatile oil having a characteristic pungent smell. In 1874 Hoffman obtained this volatile oil on steam distillation. The seed also yields about 5 per cent. mucilaginous matter. In addition to the volatile oil and mucilaginous matter the seed also contains 0·19 per cent. of alkaloid.

Estrogen therapy.—A group of immature female rats (30 days) were kept on the following diet:—

Sugar 10, casein 14, butter 15, Osbourne Mandell salt mixture 5, and rice flour 56 parts. The diet was supplemented by ½ tablet of yeast and 2-3 drops of cod-liver oil per day per rat.

The experimental rats received 3-4 drops of the cress oil in addition to the above diet, whereas the control rats received only the above diet. All the rats were killed on the 72nd day, having received the oil for six weeks. The ovary, thyroid and thymus glands were removed and weighed.

The ovaries of the experimental rats weighed consistently more than that of the control rats. The average weight of the ovaries from the experimental rats was 0·45 gm. per Kg. body weight, whereas that of the control rats was 0·25 gm. per Kg. body weight. Macroscopic examination of the ovaries of the rats receiving the oil was very significant and exhibited several hæmorrhagic follicles on the surface. No such characteristics were observed on the ovaries from control series. The uterus, thymus, thyroid and other organs did not show any abnormality. The results along with the details of histological examination will be reported later.

There was no significant difference in growth rates of the rats. The rats receiving the oil weighed comparatively less (average 83 g.) than the control ones (average 88 g.) but were significantly more active than the control series.

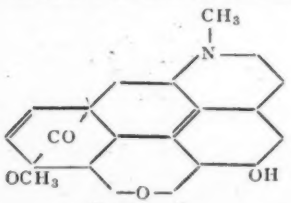
Thanks are due to Dr. V. Subrahmanyan for his keen interest.

M. B. SAHASRABUDDHE.
N. N. DE.

Department of Biochemistry,
Indian Institute of Science,
Bangalore,
December 9, 1942.

A SEARCH FOR PORPHYROXINE IN BENGAL OPIUM

PORPHYROXINE $C_{19}H_{23}O_4N$ was isolated[1] by Rakshit from the Indian variety of *Papaver somniferum* L. He represented[2] the base as a derivative of a tetrahydro codeine with the carbonyl group in a bridge position in the aromatic ring of Pschorr's codeine formula:



Porphyroxine

Later, Machiguchi[3] isolated from Japanese opium, an identical product which, however, proved to be a mixture of codamine, laudanine and meconidine. Recently[4] the view has been expressed that the constitution proposed for porphyroxine can only be accepted with reserve. It was, therefore, considered necessary to re-investigate the occurrence of porphyroxine in Bengal opium, a specimen of which was purchased as a dry powder from the Government opium factory at Ghazipore.

Following Rakshit's method[1] the total water-soluble non-phenolic bases were isolated by ether-extraction of a lime-water extract of opium. Further treatment of the crude bases with dilute hydrochloric acid gave a sparingly soluble hydrochloride (A) in an yield of about 0·34 per cent. The same hydrochloride (m.p. 265°-269° d., after a slight darkening at 240° C.) was prepared in an yield of 2·6 per cent. by extracting the total alkaloids of opium with chloroform and subsequent treatment of the alcoholic solution of the bases with dilute hydrochloric acid. On recrystallisation from alcohol the hydrochloride (A) in colourless needles melted at 276°-277° c.d. after sintering at 270° C. The free base corresponding to this was crystallised from alcohol in colourless rectangular rods. (M.P. = 152°-153° C., unchanged on mixing with a genuine specimen of codeine for which the author is deeply indebted to Prof. B. B. Dey.)

The above yield of codeine from Bengal opium is much higher than Rakshit's estimate,[5] but agrees well with that of Annet[6] and Dunnicliff.[7]

Attempts to isolate porphyroxine from the mother-liquors of codeine hydrochloride have so far proved fruitless. Only a more intensive search can finally settle the possibility that Rakshit's porphyroxine might be an impure specimen of codeine.

As the author is at present unable to continue this work, owing to other preoccupations, he leaves this question to be settled by others interested in the subject.

The author is highly grateful to Prof. L. F. Small for suggesting this problem, and to Mr. J. N. Rakshit and Col. S. S. Sokhey for their kind interest.

S. RAJAGOPALAN.

Haffkine Institute,
Bombay,
December 28, 1942.

1. Rakshit. *J.C.S.* 1919, **115**, 455. 2. Rakshit, *Ber.*, 1926, **59**, 2473. 3. Machiguchi, *J. Pharm. Soc. Japan*, 1926, **592**, 19. 4. Small, "Chemistry of the Opium Alkalcids" 1932, p. 308. 5. Rakshit, *Analyst*, 1921, **46**, 485; *Ind. J. Pharm.*, 1942, **4**, 53; *Science and Culture*, 1942, **8**, 16. 6. Annet, *Biochem. J.*, 1920, **14**, 621; *Mem. Dep. Agric. India*, 1921, **6**, Nos. 1 & 2. 7. Dunnicliff, Private Communication.

PROTOGYNY IN UGANDA *SPONTANEUM*

THE wild species of *Saccharum spontaneum* has been of particular importance and use at the Imperial Sugarcane Station X CBE. Most of the Co. canes found useful in cultivation have in them the blood of some form of *Saccharum spontaneum* and sometimes of two

forms of it. The Station now possesses one of the best collections of this species collected practically from all parts of the world. Recent additions to this collection are certain *spontaneums* from Uganda (East Africa). Two of these flowered last month and exhibited peculiarities which have so far not been recorded in any variety of *S. spontaneum* or in any species of *Saccharum*. While this is interesting in itself, the main point to which attention is now invited is their protogyny which enables their employment as ovule parents in sugarcane breeding.

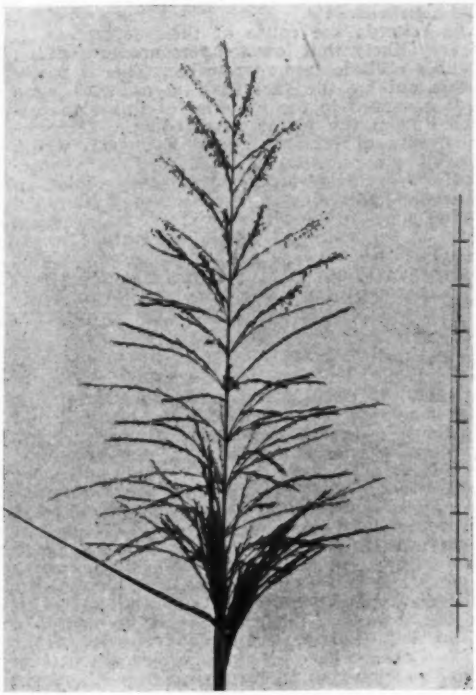


FIG. 1

The arrow of Uganda *Saccharum spontaneum*

The spikelets have opened in the upper portion. In the lower portion the stigmas are protruding from the tips of the unopened spikelets and can be made out with the help of a hand lens. The scale alongside shows inches.

In the other forms of *S. spontaneum* the spikelets begin to open only after the arrows have emerged about four inches from the leaf-sheath and the sequence of exsertion of essential organs is that the sigmas protrude as soon as the glumes are thrust apart by the swelling of the lodicules; and after an interval of about 15 minutes anthers also come out of the glumes. In the Uganda *spontaneum*, on the other hand, the stigmas begin to come out of the glumes while the arrow is still inside the leaf-sheath in the top two to three inches of the arrow. The spikelets do not open till four or five days after the protrusion of the stigmas. In Uganda *spontaneum* the flowers are thus protogynous which renders self-fertilization difficult.

FIG. 2

The spikelets of the Uganda and Coimbatore *spontaneums*

Note the stigmas protruding from the apex of the Uganda spikelet and from the sides of the Coimbatore spikelet. Note also the difference in the size of stigmas.

The diurnal opening of the *S. spontaneum* spikelets is between 7-00 and 7-15 a.m., but the Uganda *spontaneum* spikelets open only at about 9-00 a.m. Its anthers are yellow like the other *spontaneums* though somewhat deeper in colour and the tips are reddish-brown. In all the other *spontaneums* the pollen flows out easily and very little remains inside of the anther-sac. The Uganda spikelets close at 11-00 a.m., so that they remain open for two hours while in the other *spontaneums* spikelets close one hour after their opening. It will be seen in Fig. 2 that the stigmas of the Uganda *spontaneum* protrude from the apex of the spikelet while those of *S. spontaneum* Coimbatore protrude from the sides of the spikelet.

Protogeny is essentially a device to secure cross-pollination. As is well known, protandry is the more frequent form of dichogamy and occurs in most plants.[1] Even in grasses protandry is characteristic of the majority of the genera and though protogyny is rather rare, it is met with in a few genera like *Anthoxanthum*, *Pennisetum*, etc.[2]

One very good characteristic of the Uganda *spontaneums* is their erect habit. Advantage has, therefore, been taken of the protogynous nature of the Uganda *spontaneums* and one of them has now been crossed with different species of *Saccharum*. It is also proposed to cross them with certain of the *Sorghum* and

Bamboo seedlings to yield a few more trigeneric hybrids of desirable characteristics.

N. L. DUTT.
M. K. KRISHNASWAMY.
Imperial Sugarcane Station,
Coimbatore,
November 2, 1942.

1. *Strasburger's Text-Book of Botany*, 5th Eng. Ed., 1921, p. 559. 2. Bews, J. W., *The World's Grasses*, 1929, p. 22.

ON AKINETE FORMATION IN *ZYGNEMA TERRESTRIS* RANDH.

THE object of this communication is to describe a peculiar method of akinete-formation in *Zygnema terrestris* Randh. from material collected near Dhakuri in Kumaon Himalayas, and to record the presence of this alga in Kashmir.

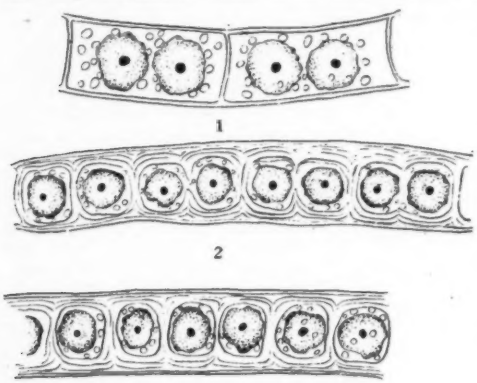
AKINETE-FORMATION

The following three modes of reproduction have been described by the present author[2,3] in this alga, so far.

1. Sclariform conjugation.
2. Lateral conjugation.
3. Aplanospore formation.

The material was collected by the author from near Dhakuri in Almora district at an altitude of about 9,000 feet above sea level in the middle of September 1939. In this material no conjugation lateral or scalariform was observed, and akinete-formation appears to be the exclusive mode of perennation.

Prior to akinete-formation cell-wall becomes thickened and lamellated. In mature akinetes cell-wall is about 6 μ thick, while in ordinary vegetative cells, it is only about 2 μ thick (Fig. 1). The peculiarity of this form lies in the fact that akinetes are not formed by the direct conversion of vegetative cells into akinetes, as in *Zygnema giganteum* Randh. or oher forms, but the vegetative cells divide into two more or less equal halves by the ingrowth of septa from the side walls, which ultimately meet in the middle (Fig. 2). So each half contains one chloroplast only surrounded by food-reserves, like starch and oil (Fig. 3). The cell-contents stain more or less black with iodine, and deep blue with Nile Blue. The akinetes are 24-27 μ broad and 18-21 μ long, *i.e.*, half as long as an average vegetative cell. There is greater economy of material in this mode of akinete-formation, for double the number of akinetes is formed. Akinete-formation is a mode of perennation in this alga in the high altitudes.



Zygnema terrestris Randhawa

FIG. 1. Vegetative cells. Mark the thin cell-wall. FIG. 2. Early stages in akinete formation. FIG. 3. Mature akinetes. Mark the single chloroplast in each akinete.

As regards the cause of their formation, it is very likely that low temperatures prevailing in high altitudes are responsible. This is partly borne out by the fact that no akinetes were ever observed in the material of this alga collected from the plains. According to Fritsch[1] in species of *Mougeotia* and *Zygnema*, which inhabit mountain-lakes in Europe with relatively low temperatures, akinete-formation is common. This alga too was collected from the alpine zone in the Himalayas and intense cold may be the cause of akinete-formation.

It is remarkable that this alga in the plains and at an altitude between 5,000 to 6,000 feet shows scalariform conjugation, between 7,000-8,000 feet shows lateral conjugation exclusively, and higher up shows akinetes only.

DISTRIBUTION

Originally collected from certain fields in Fyzabad district, in the plains of Oudh, this alga was later on collected from Kausani and Binsar in Kumaon Himalayas, Almora district. A laterally conjugating form of this alga was found near Dhakuri, at an altitude of about 8,000 feet. The material showing akinete-formation described in this paper was collected higher up in the alpine zone above Dhakuri.

On 4th August 1941, the author collected this alga from the shores of Sheshnag, an alpine lake, with glaciers on two sides, at an altitude of about 12,100 feet. This lake which is the source of Sheshnag river, a tributary of Liddar, lies on the pilgrim route to Amar Nath Cave. There was a pure growth of this alga, visible from the bridle-path in the form of a yellowish-green belt contrasting with the turquoise blue water of the lake. It formed a mat-like covering over a huge area. It was found in a purely vegetative stage, and it is likely that akinetes or conjugating material may be found in September. It is of interest to find this alga so widely distributed in the Western Himalayas from Kumaon to Kashmir.

M. S. RANDHAWA.
Deputy Commissioner's House,
Rae Bareli (U.P.),
November 28, 1942.

1. Fritsch, F. E., *The Structure and Reproduction of the Algæ*, Cambridge Univ. Press, 1935, **1**, 336. 2. Randhawa, M. S., "Observations on some Zygnemales from Northern India, Part I." *Proc. Ind. Acad. Sci.*, 1938, **8**, 144 and 149. 3. Randhawa, M. S., "*Zygnema terrestris* Randh. from the Kumaon Himalayas," *Curr. Sci.*, 1940, **9**, No. 8, 373 and 374.

RICCIA GANGETICA AHMAD

I HAVE read with interest Mr. Ahmad's paper on "Three new species of Riccia from India" published in *Current Science* for November 1942. Mr. Ahmad has missed the supplement to "The Liverworts of the Western Himalayas and the Punjab Plains" Part I; otherwise he would not have treated *R. gangeticas* as a new species. Below is the description of *R. himalayensis* St., as given by Kashyap side by side with the description of *R. gangetica* Ahmad.

R. himalayensis St.	*Riccia gangetica* Ahmad
Dicœcious or moncœcious lobes upto 8-10 mm. long. Dorsal surface green with a median sulcus. Air spaces narrow, slit-like cross-section three times as broad as high.	Moncœcious. Thalli up to 20 mm. in diameter. Dorsal surface bluish green with a median sulcus. Air spaces narrow, slit-like two or three times as broad as high.
Scales small, semilunar distant, purple or hyaline, *bent over the margin.*	Scales prominent, semilunar, colourless or pink, *never extending beyond the margins.*
Antheridia in one median row.	*Antheridia and archegonia uni- or bi-seriate along the median line.*
Spores 90-110 μ, in specimens from Negapatum upto 132 μ; dark brown to opaque.	Spores 112-134 μ, *ellipsoid*, black.
Surface reticulate, margin usually with long processes which are prolongations of the walls of the reticulations.	Surface reticulate, low walls separating the areoles, margin obscurely dentate.
In specimens from Spiti the reticulations faint (naturally the margin would be faintly dentate).	

Above comparison shows that *R. gangetica* differs from *R. himalayensis* in having (1) shorter scales, (2) uni- or bi-seriate antheridia and archegonia, (3) Ellipsoidal spores.

Reduction in scales as a result of the hygrophyllus mode of life is very common in liverworts and bi-seriate archegonia and antheridia cannot be considered as a specific difference.

Botany Department, R. S. CHOPRA.
Panjab University,
Lahore,
December 15, 1942.

REVIEWS

Mathematics: Its Magic and Mastery. By Aaron Bakst. (Chapman and Hall, London), 1941. Pp. xiv + 790. Price 21*sh.*

This book of over 700 pages of clear printing, attractive head lines, and pleasing cartoons, is a very neat and successful dressing for those mathematcial dishes that are usually offered for the general education of the public up to the matriculation standard. All those elderly "juveniles" who continue to retain a taste for figures and an interest in reading are sure to find vast enjoyment in this book. It differs from the classical treatments of amusements in mathematics for the sake of mathematics, and is largely concerned with the aplication of the methods of elementary mathematics in the various fields of human endeavour, without bothering the reader with any abstract conceptions or abstruse procedures.

The book is divided into 37 chapters with an appendix of equations and Tables. Given below are some selected chapter headings and sub-headings: Systems of Numeration (Home work was never like this $1 + 1 = 10$), the Arithmetic of Measurement, Rapid Calculations, The Grammar of Algebra (The silk stocking bargain bubble, dream of an opium eater, the family-minded fly, the arithmetical plague of Australia, the how many times ladder, a sequence for the rabbits, a clever rat, the banker's mathematics), Streamlining Everyday Computation, How to have Fun with Lady Luck, Post Office Mathematics, Man's Servant —The Triangle, The Triangle—Man's Master, the mathematics of Seeing, the Shape of Things, Escape from Flat Land, Cork-Screw Geometry, The Firing Squad and Mathematics.

A Handbook of Shellac Analysis. By M. Rangaswami and H. K. Sen, Indian Lac Research Institute, Namkum, Ranchi, 1942. Pp. 106 + xvii. Price Rs. 3-4-0.

Shellac—the commercial form in which lac is mostly exported—has remained one of India's monopolies. The Indian Lac Cess Committee, sponsored by the Government of India, has played an active part in helping to maintain the supremacy of lac in trades and industries where its special qualities are valued, in spite of keen competition from synthetic substitutes. Like many other natural products, lac varies in composition depending upon the host which feeds the parasite, the race of insect which secretes it and the season in which the crop is raised; it also depends upon the conditions of storage, the mode of treatment it receives during the various industrial operations which intervene between stick lac and shellac. Further, the uncertain and inflated prices which have ruled the shellac

market in the past have constituted a great temptation for several manufacturers to adulterate shellac with cheaper resins.

The natural and inherent factors and the unnatural and avoidable circumstances described above, have frequently disturbed the shellac market in Europe and America and foreign consumers have insisted that shellac and other forms of lac should conform to certain specifications laid down by them. The demands of modern industry are becoming more and more exacting with respect to its natural raw materials. These are expected to satisfy a certain degree of uniformity in its chemical and physical properties as revealed by standardised methods of analysis.

Valuable publications on shellac analysis have been issued by the leading importers and exporters of this commodity in America, England and also in India. In addition there are contributions on this subject from individual research workers and these have been scattered among several scientific journals. As the authors have remarked in their preface, "the various trade interests are still not agreed upon what fundamental and special tests should constitute the analysis of lac and no one method exists for the examination of any particular property."

The Indian Lac Research Institute at Ranchi has for sometime been engaged in this problem of shellac analysis and the Institute has the enviable advantage of being able to obtain genuine samples of every type and every form of lac for research. The Handbook of Shellac Analysis under review, includes a substantial portion of the experimental work and wide experience accumulated during the past twenty years. The authors have rendered a great service to the Indian lac industry by bringing together all the available methods of shellac analysis into one volume and by appraising them critically in the light of their own valuable experience. It is earnestly hoped that the Handbook will receive the wide publicity it deserves and focus attention on the necessity of evolving a uniform and universally acceptable system of analysis for the various grades and forms of shellac.

The Effect of Range of Stress on the Fatigue Strength of Metals. By J. O. Smith. (*Bulletin of the University of Illinois*, 1942, 39, No. 26, February 17.) Price 55 cents.

The important problem of the Effect of Range of Stress on the Fatigue Strength of Metals has been thoroughly studied and investigated by Mr. J. O. Smith of the University of Illinois. As a result of these investigations a new definition has been evolved for the "Endurance Limit" of a metal under fatigue. This has been defined as the maximum alternating stress which may be superimposed on a given steady stress and repeated an indefinitely large number of times without causing a fatigue fracture. The effect of range of stress on the fatigue strength has been studied with respect to a number of metals, both ductile and brittle, for notched and notch-free specimens and for various ranges of stress in which the steady stress was tension and compression. The author, however, assumes that the results obtained from direct axial tension—compression stresses are also applicable to bending merely on account of the difficulties involved in determining the value of the Ranges of Stress in Bending. This fact has yet to be confirmed by experimentation for various ranges of Bending Stresses.

Two sets of diagrams have been evolved. One The Maximum Stress—alternating stress diagram and secondly, the Steady Stress—alternating stress diagram in which the alternating stress is the Endurance Limit for the corresponding steady stress of the range of stresses. These diagrams are the modifications of the Goodman diagram and are called as such. These are very useful in determining the working stresses of metals under various ranges of stresses, and also the area of cross-section of members under those stresses. All the test data have been illustrated by means of these diagrams.

A set of conclusions drawn from all these data and a Bibliography have been added at the end of the report, which are very useful for further work on the subject.

S. K. L. NARAYANA.

Eighth Progress Report of the Joint Investigation of Fissures in Railroad Rails. By H. F. Moore. (*Bulletin of the University of Illinois*, March 1942, 39, No. 28.) Price 15 cents.

This investigation has been carried out by the Engineering Experiment Station of the University of Illinois jointly with the Association of American Railroads and the Rail manufacturers' Technical Committee. The usual Batter and Hardness measurements have been conducted on Rails in Service and a big table of results has been recorded. In this connection Messrs. R. Jensen and N. J. Alleman point out how the end hardening of rails will make the Brinnel Hardness number of the material constant, even after several million tons of traffic. Mr. R. E. Cramer has further studied this subject and finds that rails develop a sort of weeping cracks which can eventually be built up by welding. These may be due to the excessive end hardening of rails above the Brinnel Hardness number 400. These may also be due to slotting of rail ends or notches on the ground end of the rails near the railtread. But these are not substantiated by experimental results.

Finally Mr. Cramer gives a list of proposed recommended practice for control cooling of rails with or without hydrogen ingots. He also gives a number of lists to determine the manner of growth of shatter cracks well illustrated by microscopic photographs. Messrs. Alleman and H. F. Moore deal with a comparison of drop and bend tests on rails, in which they define the "Force of a Blow" and the several methods of determining the same. All of them are illustrated by a number of test results and are very useful for further work on the subject.

S. K. L. NARAYAN.

LAND MANAGEMENT IN THE PUNJAB FOOTHILLS

Land Management in the Punjab Foothills. By R. Maclagan Gorrie, D.Sc. (The Punjab Government Press, Lahore). Pp. vi + 78 + xii. Price Re. 1-6-0.

THE reviewer has found this booklet exceptionally interesting and worthy of careful study even by those who may not be directly concerned with the main subject, *viz.*, the prevention or correction of erosion. The author's object is certainly fulfilled, *viz.*, "to place in the hands of all who may be concerned with the administration of land a concise statement of the true aims of land management in language which can be understood by those who have not had a scientific training in agriculture or kindred subjects".

On almost every page some questions of importance are raised either directly or incidentally. The impact of these questions on the reader will depend on his particular view-point. To the present reviewer the outstanding impression was the sad effect on the whole agricultural economy of India of the constant quest after cheapness. This indeed is apparent even in the get-up of the booklet where economy in printing has been sought at the cost of the practical destruction of the effectiveness of the excellent photographs taken evidently with great care by the author.

Apart from the naturally depressing effect on the artistic photographer the reader is deprived of the satisfaction arising from the contemplation of good work, and there is left in fact once more the suggestion of the essential "katchaness" of Indian work. The suggestion, it may be said, if largely true, is quite unnecessary, since good work can be done in this country if only requisite measures are adopted.

At any rate this trouble should not arise with Government publications intended to stimulate better work in their own sphere by those for whom these publications are issued. In relation to the subject of the booklet the trouble of cheapness finds its main expression in the uncontrolled grazing of unlimited herds of very inferior cattle. No doubt poverty and other excuses may be found, but surely what is needed is a strong handling of the whole question, sympathetic understanding being combined with resolute firmness. The aim of necessary education should be, apart from its ultimate ethical basis, which means an awakening of social consciousness at present entirely dormant, to show the ultimate benefit accruing to all and sundry by the adoption of rational methods of cattle breeding and feeding. A few carefully selected and stall-fed animals would bring directly more profit to the farmer and indirectly would prevent great ultimate loss in the ruin of fertile areas of land.

This same principle of spending more on less, as against spreading available expenditure so thinly that its ultimate effect is virtually nil, applies not only to the problem of land management but in many other directions where public money is concerned. Thus in a sphere with which the reviewer is familiar, *viz.*, water supply and sewage disposal, it is of little use to spread available money so thinly that real purification of the water before and after use is not attained. If the money was intensively spent so that complete purification of a portion was actually realized, this would really give better results than the same amount of money thinly spread, not only for technical reasons which need not be here discussed but also for what is perhaps of equal importance, *viz.*, that the portion properly handled would provide a standing model to be followed in later developments.

It is of interest to compare the recommendations in the booklet under review with those made many years ago in the famous report on the "Improvement of Indian Agriculture" by the reviewer's late and highly esteemed friend, Dr. J. A. Voelcker. Many of Dr. Voelcker's suggestions have since been carried out with great benefit to the country and in other directions it can be seen from Dr. Gorrie's pages that these recommendations have been developed still further. Thus, for example, in the necessary production of organic manure the old-new method of "composting" has resulted, if scientifically carried out, in a great increase of valuable fertilizer without in many cases an entire deprivation of cowdung cakes for fuel purposes. For this last much criticised practice good excuses may sometimes be found, *viz.*, in the absence of other fuel, especially it may be said under war conditions, and in the peculiarly slow-burning efficacy of cowdung.

The distinction made between the valuable qualities of sheep and goats is almost reminiscent of Scripture. Yet it appears that even goats have very special uses provided they are intelligently bred and controlled. No one who has had charge of a woodland or even a garden will deny for a moment the absolute wickedness of the ordinary goat, who will destroy a valuable tree very quickly by eating round the bark everywhere within reach. Unfortunately it is not only four-footed goats who are guilty of this practice, but surreptitious two-legged seekers after cheap fuel who chop the bark from the lower portions of magnificent old trees, entirely reckless of their possible ultimate destruction. This kind of thing which every dweller in the Indian countryside, or country property owner, has met sometimes, raises the question whether the excessive "respect for property", the evil of which is now becoming widely recognized by thoughtful people, may not at one time at any rate have had some useful basis in preventing indiscriminate stealing. No one would justify the harsh laws formerly existing in England against sheep-steeling and theft in general, but it is possible that it may not have been without effect in developing subconsciously a regard for the Eighth Commandment.

The whole outlook on economics especially in relation to social welfare demands far more attention than it is yet receiving by the general public. At the same time it is encouraging to know that the movement for a rational view-point and for a true concept of wealth

is now finding utterance in the British Parliament, and the Economic Reform Club and Institute of London beginning in a small way is now greatly increasing its scope and usefulness. All these large questions of land management dealt with in the booklet under review would be far more easily and promptly handled if the bogey of financial stringency was not always raised. The enormous expenditure on war material now going forward is opening the public's eye to the fact that money is only a token which under proper public management, as apart from profit-making banking companies, can be made to correspond with the labour and other services required for these measures of improvement. The instance given in the booklet of valuable results from co-operative labour shows how when there is a will and understanding great things are possible.

It may be hoped that Dr. Gorrie's booklet will be of value not only in India but in other parts of the world where erosion problems have to be faced. In the Federated Malay States, for example, it was pointed out to the reviewer many years ago that owing to the accumulation of flood-borne silt the beds of several of the rivers had risen to the arches of the bridges. Apart from suitable training of such rivers the value in many cases of the silt as manure should not be forgotten. This point is made by Dr. Voelcker but possibly because the conditions are not comparable in the areas referred to in the booklet, this aspect of the question is not emphasised by Dr. Gorrie.

A word may finally be said with regard to fodder reserve. It is rather curious that while at one time the value of spineless cactus was recognised and much advertisement was given to Luther Burbank's efforts in developing such a plant, work which has been done in India in comparatively recent years seems to have been forgotten. Reference may be made to a valuable article by Dr. Burns in *Indian Farming* for October 1940 in which he mentions several efforts made in former years to develop spineless cactus in India, amongst others an attempt by the present reviewer and his colleagues at the Indian Institute of Science. This was so far successful that an excellent growth of the plant was still spineless after nearly fifteen years.

Altogether it will be seen that the booklet is full of practical and at the same time thought-provoking proposals and it may be hoped that it will have a wide circulation not only amongst specialists, but, as the author hopes, among the educated public generally.

GILBERT J. FOWLER.

CENTENARIES

Potter, Nathaniel (1770–1843)

NATHANIEL POTTER, an American epidemiologist, was born at Easten in 1770. He graduated in medicine in 1796 from the University of Pennsylvania. He became the first professor of medicine in the Medical College of Maryland on its establishment in 1807 and kept that position till his death. He wrote profusely and was Editor of *Baltimore medical and philosophical lycaeum* (1811) and joint-editor of *Maryland medical and surgical journal* (1840-43). The fame of Potter rests largely on his service to the epidemiology of yellow-fever. He established its non-contagiousness by lending himself to experimentation. In 1797 he tied up around his head a piece of muslin dipped in the perspiration of a patient dying with yellow-fever and keeping it all the night. In 1798, he inoculated himself with the perspiration of a yellow-fever patient in the last stages of the disease. Potter died at Baltimore, January 2, 1843.

Fitch, John (1743–1798)

JOHN FITCH, an American inventor, was born at Windsor, Hartford county, January 21, 1743. After spending five years in an elementary school, he was put on his father's farm even when he was but ten. As he was a weak child, farm work made his life unhappy and so after five years, he changed over to the service of a shop-keeper. Finding this too unsuitable, he shifted from one calling to another, until at last he turned his attention to the invention of steam-boat in 1785. By 1787, his first steam-boat was launched on the Delaware river at Philadelphia in the presence of the members of the Congress. In 1788 he launched a bigger boat, 60 feet long, and carried as many as 30 passengers, covering 20 miles in about 3 hours. In 1790, he built a still larger boat and this was put to regular service and Fitch got a patent from the U.S.A. and from France. In 1791, he started work on his fourth boat, named *Perseverance*; but it was destroyed before completion by a violent storm. This disaster virtually ended his career. After sojourning for four years in France and other places in search of a more favourable opportunity to realise his ambition, Fitch died in disappointment at Bandstown, July 2, 1792.

S. R. RANGANATHAN.

University Library,
Madras,
January 4, 1943.

SCIENCE NOTES AND NEWS

House-freqenting Flies.—Fly reduction is a question of efficient sanitation; sanitation is no less a question of efficient fly control. This fact of intimate inter-relationship between the fly and sanitation in a town or village has been lucidly described in the Health Bulletin No. 31 (*"The House-frequenting Flies, Their Relation to Disease and Their Control"*, by I. M. Puri, M.Sc., Ph.D.). As the author has, however, pointed out more than once, the amazing fact about this relationship is its failure to impress sufficiently the greater portion of the public, of its importance, to human welfare. The author is of the opinion that the public—literate as well as illiterate—need to be rigorously educated and constantly reminded about the basic facts of human diseases like typhoid, cholera, tuberculosis and infantile diarrhœa, etc., and the close relationship of the fly to these diseases.

By far the most prevalent house-frequenting fly is the common fly belonging to the genus Musca, having a number of different species in various parts of India. From the public health point of view, some eight species of Musca, four species of Lucilia, three of Calliphora, three of Chrysomia and two of Sarcophaga, are of considerable importance to India. The author of this Bulletin has done a service to the cause of sanitation in India by providing very simple keys for the identification of the different species of flies under each genus. The author has also dealt with the question of control of flies in a rather exhaustive manner, under different heads, namely, Prevention of Egg-Laying; Chemical Control of Fly-breeding; Biological Control of Fly-breeding; Control of Fly-breeding in Trenched Night-soil; and Measures against Adult Flies, involving screening, baiting, trapping and spray-killing.

Jute Substitute in Cuba.—It is understood that an experiment is being made in Cuba under Government backing to determine the commercial possibilities of *Malva blanca*, a plant which grows wild in Cuba and Venezuela. The fibre from this plant, it is claimed, is a good substitute for jute and can be made into bags for sugar, rice and coffee at a cost not greater than those made from jute. It is said that arrangements have been completed for the erection of a factory in Cuba for converting the *Malva* fibre into bags. This factory is expected to be ready by April next and will have an annual capacity of 6,000,000 bags.

Jute as Substitute for Wool.—In the Technological Research Laboratories of the Indian Central Jute Committee some knitted fabrics from jute ply-yarns were prepared and experiments are in progress to see if softening treatments can be found to make the material suitable to replace wool for such purposes as knitted jerseys, scarfs, etc.

Principles of Stellar Dynamics. By Prof. S. Chandrasekhar.—This book represents one of the most important recent additions to astronomical literature. The titles of the five chapters are: Kinematics; The Time of Relaxation of a Stellar System; Galactic Dynamics; The Dynamics of Differential Motion; General Dynamics of Stellar Systems; Spiral Structure; and The Dynamics of Star Clusters. Not only does the book provide a most excellent introduction to the whole field of Stellar Dynamics, but in it are contained highly illuminating discussions of some of the major current problems in astronomy, among them the probable interpretation of spiral structure. The book is one of the series of Astrophysical Monographs sponsored by the *Astrophysical Journal*.

Lady Tata Memorial Trust: Scientific Research Scholarships for 1943-44.—Applications are invited for six Scientific Research Scholarships of the value of Rs. 150 per month each for the year 1943-44.

The Scholarships are open to men and women, and will be tenable for a period of twelve months commencing from the 1st July 1943. Any or all the Scholarships may be extended for a further period of twelve months, within the discretion of the Trustees. All old scholars who desire renewal should re-apply.

Applicants, who must be of Indian nationality, must be Graduates in Medicine or Science of a recognised University. They must undertake to work whole-time and will be debarred from private practice. In the duration of the period of his scholarship or award the recipient of the benefit shall devote himself to the work before him to the entire satisfaction of the Trustees, who reserve the right to withold payment on the recommendation of the Advisory Committee.

The subject of scientific investigation which they may select must have a bearing directly or indirectly on the alleviation of human suffering from disease.

Application must be forwarded through the Director of a recognised Research Institute or Laboratory where the candidate proposes to work and must be accompanied by a letter from the Director stating that he has critically examined the details of the proposed Research, that he approves of the general plan and that he is willing, as far as possible, to guide and direct the investigation and give laboratory facilities.

Candidates will be required to furnish the following additional information in their application, along with certificates of physical fitness and character:—

(*a*) Full Name, (*b*) Age, (*c*) Sex, (*d*) Permanent Address, (*e*) Details of Academic Career, (*f*) Particulars of their past and present Research qualifications, (*g*) Particulars of the proposed Research, (*h*) What other emoluments, scholarships and pay or any other financial support from friends or relations they are or will be in receipt of

during the period they are Scholars and the amount, if any.

Applicants must give (*a*) a short resume on the subject indicating present state of knowledge and (*b*) details of the proposed research indicating (*i*) the methods intended to be employed, (*ii*) previous experience in the use of these methods and (*iii*) the experiments to be carried out.

Applications, which must be typed, must give full particulars in the order indicated above and must be addressed to the Secretary, THE LADY TATA MEMORIAL TRUST, BOMBAY HOUSE, BRUCE STREET, FORT, BOMBAY, so as to reach him not later than 15th March 1943.

Indian Botanical Society: List of the Office-bearers for 1943.—*President*: Dr. K. D. Bagchee, Dehra Dun; *Vice-Presidents*: Principal P. Parija, Cuttack, and Prof. M. A. Sampathkumaran, Bangalore; *Treasurer*: Prof. M. O. P. Iyengar, Madras; *Secretary*: Prof. G. P. Majumdar, Calcutta.

Elected Members of the Executive Council: Mr. I. Banerji, Calcutta; Prof. Y. Bharadwaja, Benares; Prof. F. R. Bharucha, Bombay; Prof. S. R. Bose, Calcutta; Prof. H. Chaudhari, Panjab; Dr. A. C. Joshi, Benares; Prof. B. C. Kundu, Calcutta; Dr. T. S. Mahabale, Ahmedabad; Dr. P. Maheswari, Dacca; Rai Bahadur Prof. K. C. Mehta, Agra; Dr. B. P. Pal, New Delhi; Prof. M. Sayeed-ud-Din, Hyderabad (Deccan).

Editorial Board: Prof. S. P. Agharkar, Calcutta; Prof. H. Chaudhuri, Panjab; Prof. M. O. P. Iyengar, Madras (*Chief Editor*); Prof. G. P. Majumdar, Calcutta; Principal P. Parija, Cuttack; Prof. B. Sahni, Lucknow.

National Institute of Sciences of India.—The Eighth Annual General Meeting of the National Institute of Sciences of India was held on Friday, the 1st January 1943, in the University College of Science, Calcutta. The Report of Council for the year 1942 together with the audited statement of accounts was adopted and the Presidential Address by Dr. Baini Prashad, O.B.E., on "Conservation of Wild Life in India" was read.

The following Officers and Members of Council for the year 1943 were elected:—

President: Sir Jnanchandra Ghosh, Bangalore; *Vice-Presidents*: Prof. S. K. Mitra, Calcutta, Mr. D. N. Wadia, Colombo; *Treasurer*. Rai Bahadur K. N. Bagchi, Calcutta; *Foreign Secretary*: Prof. J. N. Mukherjee, Calcutta; *Secretaries*: Prof. S. P. Agharkar, Calcutta, Dr. C. S. Fox, Calcutta; *Editor of Publications*: Rai Bahadur S. L. Hora, Calcutta; *Members of Council*: Dr. K. Bagchee, Dehra Dun, Sir S. S. Bhatnagar, Delhi, Dr. F. H. Gravely, Kodaikanal, Prof. B. C. Guha, Calcutta, Dr. B. S. Guha, Benares, Dr. M. Ishaq, Aligarh, Dr. D. S. Kothari, Delhi, Prof. K. G. Naik, Baroda, Prof. V. V. Narlikar, Benares, Principal P. Parija, Cuttack, Dr. F. G. Percival, Jamshedpur, Dr. K. R. Ramanathan, Poona, Mr. B. Rama Rao, Bangalore, Prof. P. Ray, Calcutta, Prof. M. R. Siddiqi, Hyderabad (Dn.), Dr. N. K. Sur, Calcutta, Dr. K. Venkataraman, Bombay; *Ex-officio Members of Council*: Sir R. N. Chopra, Jammu-Tawi, Sir Lewis Fermor, Bristol, England, Dr. B. Prashad, Benares, Prof. M. N. Saha, Calcutta.

We acknowledge with thanks receipt of the following:—

"Journal of Agricultural Research," Vol. 65, Nos. 3 and 4.
"Agricultural Gazette of New South Wales," Vol. 53, No. 10.
"Allahabad Farmer," Vol. 16, No. 6.
"Annals of Biochemistry and Experimental Medicine," Vol. 2, No. 3.
"Journal of the Indian Botanical Society," Vol. 21, Nos. 5 and 6.
"Journal of Chemical Physics," Vol. 10, No. 9.
"Journal of Indian Chemical Society," Vol 19, Nos. 9 and 10.
"Experiment Station Record," Vol. 87, Nos. 2 and 3.
"Transactions of the Faraday Society," Vol. 38, No. 10.
"Indian Forester," Vol. 69, No. 1.
"Bulletin of the Indian Central Jute Committee," Vol. 5, No. 9.
"Review of Applied Mycology," Vol. 21, Pt. 9.
"Bulletin of the American Meteorological Society," Vol. 23, No. 5.
"Indian Medical Gazette," Vol. 77, No. 12.
"Nature," Vol. 150, Nos. 3798, 3806 and 3808.
"Journal of Nutrition," Vol. 24, No. 3.
"American Museum of Natural History," Vol. 50, No. 2.
"Indian Journal of Physics," Vol. 16, Pt. 5.
"Canadian Journal of Research," Vol. 20, No. 9.
"Science," Vol. 96, Nos. 2487-2490.
"Sky," Vol. 1, No. 11; Vol. 2, No. 1.
"Science and Culture," Vol. 8, No. 7.
"Indian Trade Journal," Vol. 147, Nos. 1904-1906; Vol. 148, No. 1907.
"Indian Journal of Veterinary Science and Animal Husbandry," Vol. 12, Pt. 3.

BOOKS

Temperature Control. By A. J. Ausley. (Chapman and Hall, London), 1942. Pp. viii + 127. Price 13*sh* 6*d*.

Electrical Engineering Practice, Vol. II, Fifth Edition. By J. W. Meares and R. E. Neale. (Chapman and Hall, London), 1942. Pp. xii + 668. Price 35*sh*.

Modern Synthetic Rubbers. By Harry Barron. (Chapman and Hall, London), 1942. Pp. viii + 274. Price 25*sh*.

Biochemistry and Morphogenesis. By Joseph Needham. (Cambridge University Press, London), 1942. Pp. xiii + 785. Price 52*sh*. 6*d*.

SUPPLEMENT TO CURRENT SCIENCE

Vol. XII] JANUARY 1943 [No. 1

THE STRUCTURE AND PROPERTIES OF DIAMOND*

BY

SIR C. V. RAMAN

AS is well known, a study of the forms and properties of crystals enables them to be grouped in 32 symmetry classes, five of which appear in the cubic system. These symmetry classes are identified in theoretical crystallography with the 32 point-groups, these having as their subclasses the various space-groups which specify the patterns of atomic arrangement within the crystal. In actual experience, crystals exhibiting a high degree of symmetry often contain far fewer atoms in each lattice cell than the full number of asymmetric particles required by theory to give such symmetry. This becomes possible when the atoms are located at special positions in the space-lattice, namely, at the intersection points of the axes and planes of symmetry of the crystal. If the atoms were mere geometrical points, their positions alone would determine the symmetry of the crystal. Actually, however, the atoms with their enveloping electronic clouds have a finite extension. It follows that the atoms themselves must possess certain symmetry characters to permit of their occupying such privileged positions in the space-lattice. The orientations of the atoms must accordingly be taken into consideration, and should be such as to satisfy the symmetry requirements of the crystal. Indeed, it may well happen that in an actual case, the orientations of the atoms are such that the crystal has a lower degree of symmetry than would be the case if the atomic positions alone determined its form and physical properties.

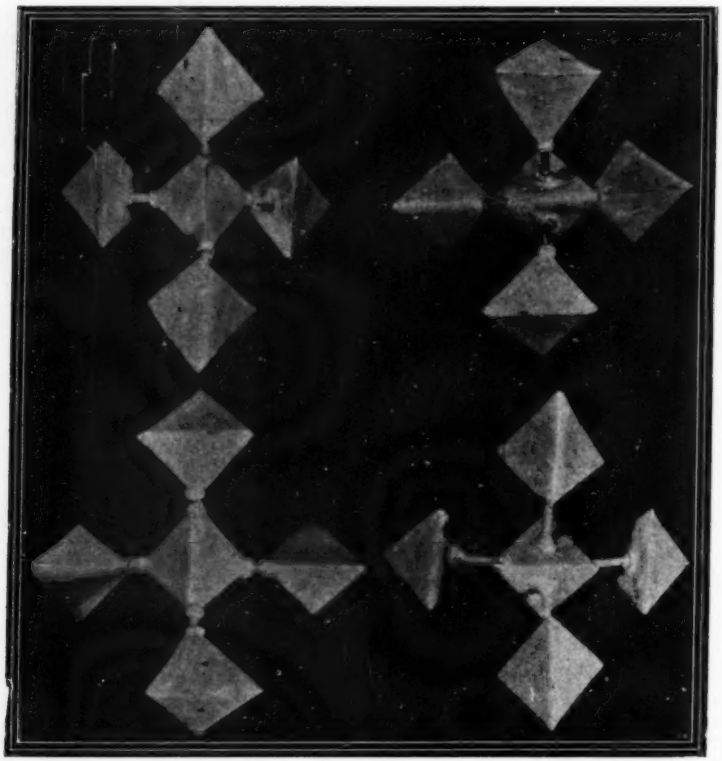
2. The Allotropic Modifications of Diamond

That a situation of the kind stated above may arise in the case of a diamond is *a priori* evident. As is well-known, the structure of this crystal embodies two interpenetrating face-centred cubic lattices of carbon atoms so located that each atom

* Presidential Address to the Eighth Annual Meeting of the Indian Academy of Sciences, at Bangalore, on the 26th December 1942.

in either lattice is symmetrically surrounded by four atoms in the other. The number of atoms per unit cubic cell in the structure is eight, four belonging to each lattice. To permit of such a simple structure for a cubic crystal, each carbon atom must itself possess a high degree of symmetry. The minimum symmetry which must be assumed is that of a tetrahedron. Assuming the atoms to possess only tetrahedral symmetry, the question arises as to how they are orientated in the unit cell. Several distinct possibilities may be envisaged. We may, for instance, assume each atom to be orientated in the same way as its four nearest neighbours along the body-diagonals of the cube, in the positive or negative sense. The structure would then not possess any centre of symmetry and would belong to the space-group T_d^2 in the hexakis-*tetrahedral* class of symmetry (E. V. Chellam, 1942). Alternatively, each atom may be oppositely orientated to its four nearest neighbours. Here again, there

I (*a*) I (*b*)



II (*a*) II (*b*)

FIG. 1

Possible orientations of the carbon atoms in diamond.
(Models and photographs by Dr. C. S. Venkateswaran)

are two distinct possibilities, since either the vertices or the bases of the opposing tetrahedra may face each other. In either of these two cases, it is apparent that the crystal would exhibit the full symmetry of the cubic system, its space-group being O_h^7 in the hexakis-*octahedral* class. It is thus seen that there are four distinct possibilities, in two of which the diamond has only tetrahedral symmetry, and in the other two, the full symmetry of the octahedron.

It is possible that we may also be concerned with combinations (in a quantum-mechanical sense) of the different arrangements represented in Fig. 1. If, for instance, types I (*a*) and I (*b*), or if similarly types II (*a*) and II (*b*) are superposed, the individual atoms as well as the crystal as a whole would possess octahedral symmetry. On the other hand, combinations of I and II (one each) would make the atoms in the two lattices possess different symmetries, while the crystal as a whole would possess only tetrahedral symmetry. Mr. G. N. Ramachandran (1942) has shown that all the different arrangements here contemplated would give zero intensity for the X-ray reflections by the (200) planes of the crystal, in agreement with observation. On the other hand, the so-called "forbidden" X-ray reflections, *e.g.*, those by the (222) and (622) planes, would appear with some models and not with others, the actual intensity varying with the combination chosen.

3. The Crystallographic Facts

Mineralogists are familiar with various special types of twinning as the result of which the true symmetry of a crystal is often disguised and forms of higher symmetry are closely imitated. In the hexakis-*tetrahedral* class, for example, an interpenetration twinning of "positive" and "negative" tetrahedra would enable the forms of highest symmetry of the cubic system to be exhibited. Since the positive and negative forms are physically similar and differ only in external orientation, such interpenetration would not easily be detectable by ordinary methods. The true symmetry of the crystal in such cases may, however, be inferred from its physical properties and also from the evidence of such facts as the unequal but symmetric development of four out of the eight octahedral faces, the appearance of octahedra with grooved edges, as also occasionally of single tetrahedra, of duplex tetrahedra, and of complete crystals exhibiting the 24 faces of the hexakis-*tetrahedron*. That the majority of diamonds have in reality only tetrahedral and not octahedral symmetry and that the higher kind of symmetry exhibited by the observed crystal forms arises from an interpenetration of positive and negative tetrahedra, is indeed evident from a study of the observed crystal forms of diamond. Examples illustrating each of the special crystal forms mentioned above will be found pictured by Sutton in his book (1928) based on 35 years' study at the South African mines. There is no doubt, however, that diamonds do occasionally appear which possesses the true symmetry of the hexakis-*octahedral* class.

The exact nature of the interpenetration twinning which appears in diamond cannot, of course, be predicted from purely theoretical considerations. It may, of course, be the case that the boundaries of separation within the crystal of the

interpenetrating species are wholly arbitrary, *viz.*, of irregular form and variable size. This may well happen when the two types are physically similar, *e.g.*, the positive and negative tetrahedra of the hexakis-*tetrahedral* class. On the other hand, it may reasonably be expected that interpenetration twinning of physically different modifications may also, as in the case of quartz, occur parallel to certain crystallographic planes. An inspection of the models illustrated in Fig. 1 suggests that when twinning layers appear in diamond, they should be parallel to the octahedral planes. It is noteworthy in this connection that a lamellar structure parallel to one or more of the cleavage planes of the crystal is a characteristic feature exhibited by certain diamonds. The observed facts thus find a natural explanation in the ideas set forth above.

4. The Infra-Red Absorption of Diamond

Since the difference between the tetrahedral and octahedral types of diamond arises only from the relative orientations of the atoms, neither variety of diamond would give any indication of electric polarity. A striking difference should, however, appear between the two kinds of diamond in respect of their infra-red absorption spectra. For the tetrahedral variety of diamond lacks a centre of symmetry, while in octahedral diamond this is present. Accordingly, a periodic motion of the two interpenetrating lattices with respect to each other should give rise to an oscillating electric moment in tetrahedral diamond and should therefore be infra-red active, while in octahedral diamond such oscillation would give zero moment and would be infra-red inactive. In both cases, however, such oscillation should give rise to a periodically varying optical polarisability and should therefore be active in light-scattering. As was first shown by Nagendra Nath (1934), the intense line with a spectral frequency shift of 1332 wave-numbers which appears in the light-scattering by diamond is due to such an oscillation of the interpenetrating lattices. This frequency corresponds to a wave-length of about 8 μ in the infra-red spectrum. The well-known fact that an intense infra-red absorption in the neighbourhood of this wave-length is exhibited by the majority of diamonds, while such absorption is absent in a less common variety of diamond thus receives a simple and natural explanation. Indeed, this variation in the infra-red behaviour furnishes the clearest proof that we are dealing with distinct allotropic modifications of diamond.

5. The Luminescence of Diamonds

One of the most remarkable properties of diamond is the visible luminescence which it exhibits under ultra-violet irradiation. Unlike that of pearls or rubies, the luminescence of diamond varies very greatly from specimen to specimen, both in intensity and colour. This is illustrated in Fig. 2 of which the left and the right halves are photographs of the same jewel taken respectively by ordinary reflected light and by the luminescence in ultra-violet light. The 88 diamonds with which the jewel is set (unlike the pearls, rubies and emeralds also seen in it) luminesce with enormously different intensities. Indeed, only the more strongly luminescent diamonds have come out in the picture owing to the moderate

exposures used, while the rest remain invisible. In the majority of diamonds, the colour of the emitted light is blue. Greenish-blue, green or greenish-yellow luminescence is, however, also observed in some diamonds. Strongly blue-fluorescent diamonds show a greenish-yellow phosphorescence which continues when the ultra-violet irradiation is cut off. Even when the luminescence is of the same colour,—blue for example—its intensity may vary by a large factor—up to say 10,000 in different diamonds.

The spectroscopic studies of P. G. N. Nayar (1941) and of Miss Anna Mani (1942) at Bangalore have greatly advanced our knowledge of the luminescence of diamonds. These investigators have found that in spite of the enormous differences mentioned above, the luminescence spectra of all diamonds (irrespective of their origin) are essentially similar and that this is also the case for the associated absorptions in the visible region of the spectrum. The principal features in all the spectra are the two narrow electronic bands at 4152 A.U. and 5032 A.U. respectively, appearing as bright lines in emission and as dark lines in absorption. Other radiations appear at longer wave-lengths in emission and at shorter wave-lengths in absorption than these electronic bands; these frequencies of

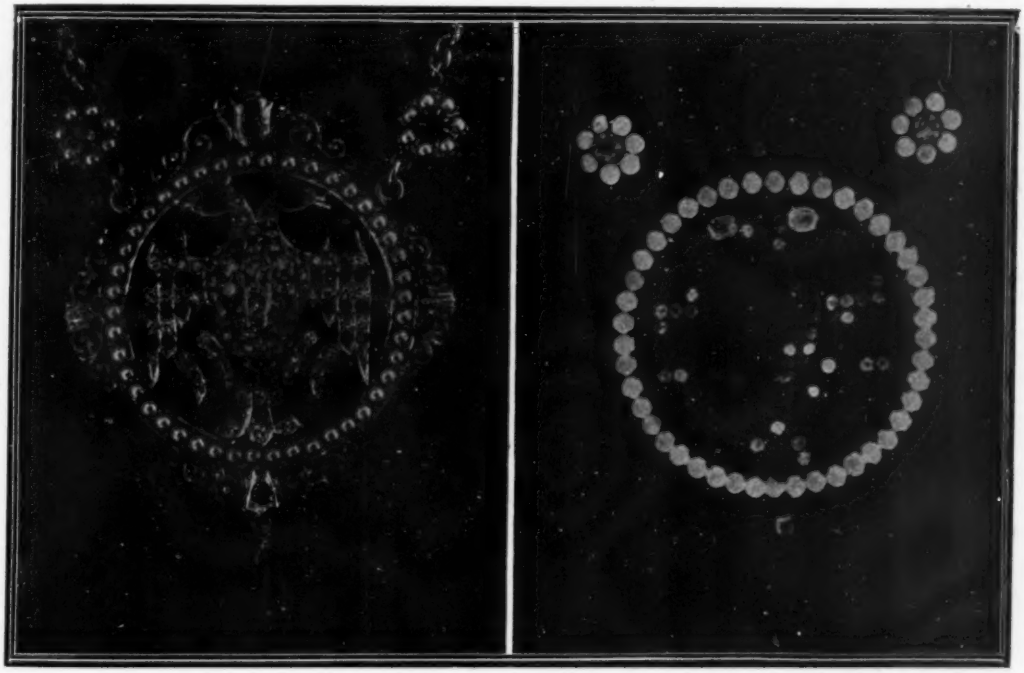


FIG. 2

Luminescence of diamonds, pearls and rubies.
(Photographs by Mr. T. M. K. Nedungadi)

emission and of absorption in every case exhibit perfect mirror-image symmetry about the electronic frequencies, thus showing that the frequency differences represent the vibration-frequencies of the crystal lattice. The differences in intensity and colour of the luminescence are brought about the variation of the absolute and relative intensities of the electronic emissions at 4152 A.U. and 5032 A.U. as well as of the associated radiations of longer wave-lengths. Corresponding differences in the absorption intensities are also exhibited.

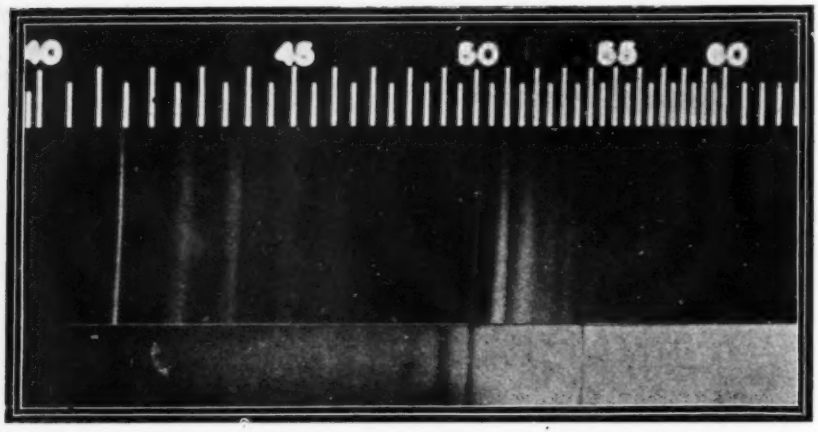


FIG. 3

Luminescence and absorption spectra of green-fluorescent diamond at liquid air temperature. (Photographs by Mr. P. G. N. Nayar)

The spectroscopic evidence clearly suggests that the luminescence is a characteristic property of diamond itself and not of any extraneous impurities which may happen to be present. This indication is further strengthened by the definite correlation which is found between luminescence and the other properties which differentiate the allotropic modifications of diamond. It is noticed, for instance, that diamonds which exhibit a blue luminescence, even if only feebly, possess the other properties, *e.g.*, the absorption in the near ultra-violet, which characterise the lower type of symmetry. On the other hand, if diamond is completely non-fluorescent, it is usually found to be of the higher type of symmetry. Another interesting fact is that the fractured edges of cleavage plates of diamond luminesce far more strongly than either the polished faces or the interior of the crystal. This is an indication that the luminescence is excited by a purely physical cause, namely, a disturbance of the regularity of the crystal structure. The variations in the intensity of the luminescence are then readily explicable as arising from the variation in the number and extent of such irregularities within the diamond. It is evident that an intimate interpenetra-

tion of positive and negative tetrahedra in the diamond of lower symmetry, if it occurs, would constitute a disturbance in the regularity of crystal structure. Such interpenetration should therefore operate as an exciter of luminescence in diamond of this type, its intensity being determined by the area and distribution of the surfaces of separation. It is then unnecessary to postulate the presence of extraneous impurities in the diamond, and indeed if such impurities were the cause of luminescence, it would be difficult to understand why diamonds having the higher type of symmetry do not exhibit luminescence to anything like the same extent. On our present view, the latter fact finds a natural explanation in the circumstance that such interpenetration does not exist in the octahedral variety of diamond. The chemical or impurity theory is also discredited by the observation that strongly blue-luminescent diamonds are often of the highest quality in respect of transparency and freedom from colour.

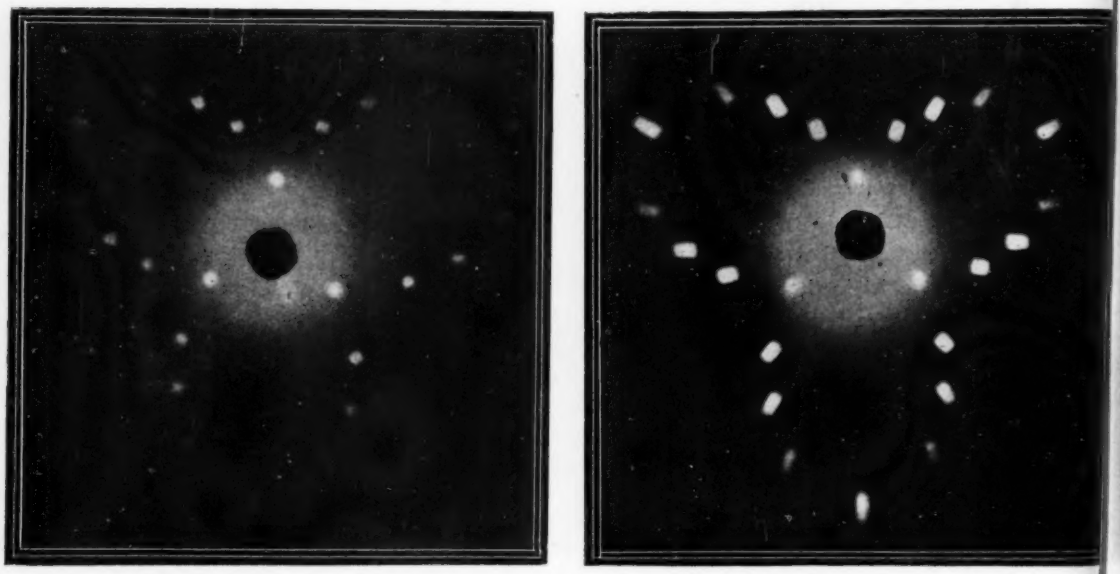
6. X-Ray Phenomena

The explanation of the luminescence of diamond put forward above has found striking support in an investigation by P. S. Hariharan (1942) of the X-ray reflections by diamond, both by the Laue and the Bragg methods, in the latter case with oscillating crystals. He found that the X-ray reflections increased conspicuously in intensity *pari passu* with the strength of the blue luminescence of the diamond under ultra-violet irradiation. His results leave little doubt that the exciting cause of luminescence is to be found in the irregularities of crystal structure. He also found that the diamonds which belong to the lower symmetry class and exhibit the blue luminescence with the least observable intensity are also the diamonds which give the least observable intensities of X-ray reflection and are therefore the nearest approach to the ideal diamond. *Per contra*, the diamonds which are non-fluorescent and belong to the higher symmetry class give extremely large intensities of X-ray reflection. The (111) Laue spots in the X-ray patterns of these latter crystals show a fine ripple-like structure of straight lines parallel to the atomic reflecting layers; from this, it may be inferred that the atomic layers in these diamonds are not strictly plane but have a periodic waviness or rugosity. The enormously increased strength of the Bragg reflections given by an oscillating crystal of this class thereby becomes intelligible. It is scarcely to be doubted that these rugosities made evident by the X-ray reflections are closely associated with the lamellar structure of these diamonds and with the streaky restorations exhibited by them in the polariscope which run parallel to one or more of the octahedral cleavage planes of the crystal.

The difference between the tetrahedral and octahedral types of diamond also manifests itself in respect of the phenomenon of quantum or modified X-ray reflection. All diamonds of the tetrahedral class, whether weakly or strongly luminescent, exhibit the triple quantum reflections by the (111) planes in a conspicuous manner. These reflections have been explained by the present writer as due to the excitation of the lattice vibrations of wave-number 1332 by the impact of the X-ray photons. Certain writers, notably Born and Lonsdale, have, on the other hand, supported the suggestion

that they may arise from a "peculiar state of strain having cubic symmetry present in such diamonds". It is obvious that a state of strain having cubic symmetry cannot possibly maintain itself in a finite crystal free from external stress, and that even if such strain existed, it would not give any observable effect other than a minute alteration of the crystal spacings. It is also important to remark that it is precisely the kind of diamond which exhibits the quantum X-ray reflections that can be obtained as cleavage plates completely from any strain detectable between crossed nicols. It is also found that such strain-free plates exhibit the quantum reflections to exactly the same extent as other plates of the same variety of diamond which show a strong and irregular restoration of light between crossed nicols as the result of visible faults or inclusions. These facts are sufficient to show that the *ad hoc* suppositions made by Born and Lonsdale are wholly without any physical foundation.

As already mentioned, the classical X-ray reflections of the octahedral variety of diamond are extremely intense. Remarkably enough, however, the diamonds of this class fail to exhibit the triple quantum reflections. This is regarded by Born and Lonsdale as a refutation of the ideas put forward by the present writer for explaining the phenomena observed with the other type of diamond. A closer consideration of the facts shows, however, that this difference in X-ray behaviour actually forms



I. Weakly fluorescent tetrahedral diamond

II. Strongly fluorescent tetrahedral diamond

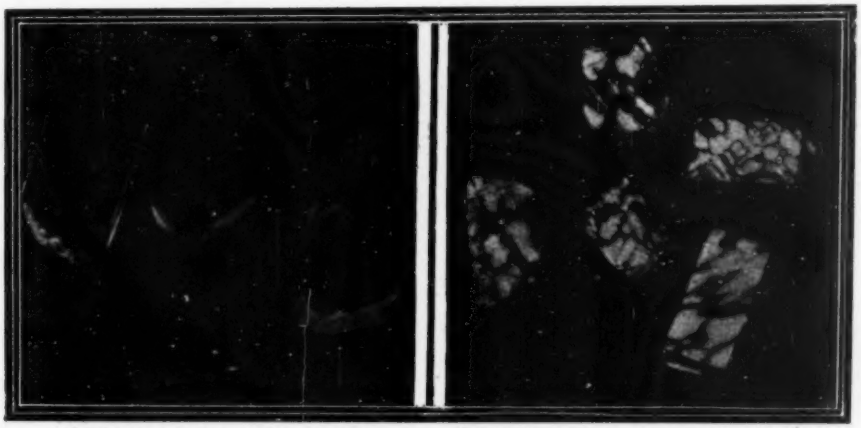
FIG. 4

Laue patterns of weakly and strongly blue-fluorescent diamonds.
(Photographs by Dr. R. S. Krishnan)

strong evidence for the correctness of the views put forward by the present writer. It will be recalled that the two types of diamond differ in their infra-red behaviour in respect of the lattice vibration of wave-number 1332, this being inactive in octahedral diamond and active in the tetrahedral variety. This difference is a direct consequence of the difference in crystal symmetry. Similar considerations of crystal symmetry may be expected also to apply to the quantum-mechanical excitation of the same lattice vibration by the X-ray photons. The appearance of the quantum X-ray reflections with one kind of diamond and their non-appearance in the other kind then follows as an immediate consequence. In other words, this difference in X-ray behaviour of the two kinds of diamond is actually a proof that the movement of the crystal lattice which gives rise to the modified X-ray reflection is the same high-frequency vibration in respect of which the two types of diamond show such a remarkable difference of behaviour in infra-red absorption.

7. Photo-conductivity

Diamond, as is well known, exhibits the very interesting property of becoming electrically conducting when illuminated by visible or ultra-violet light. Gudden and Pohl who studied this effect found that the diamonds which freely transmit ultra-violet radiations of shorter wave-length than 3000 A.U. exhibit the effect in a more striking manner than the diamonds which are practically opaque beyond that wave-length. They attributed this difference to the impurities which they assumed were present in the less transparent variety of diamond. This assumption, of course, has



(A) 5 Strain-free plates of tetrahedral diamond

(B) Strain-patterns in 5 plates of octahedral diamond

Fig. 5

Plates of diamond between crossed nicols.
(Photographs by Mrs. K. Sunanda Bai)

no foundation, and we have to seek for a different explanation of the very remarkable experimental facts. Robertson and Fox (1934) showed that the greater transparency in the ultra-violet goes hand in hand with the absence of infra-red absorption at the wave-length 8 μ. It follows that the difference in ultra-violet transparency also arises from the difference in crystal structure, the tetrahedral diamonds being the less transparent and the octahedral diamonds the more. This difference in transparency cannot however, by itself, account fully for the striking differences in photo-conductivity, and it is evident that we have to seek for a further explanation on the same basis as for the difference in the luminescence properties. This question has been examined by Mr. D. D. Pant (1942) who has made observations with numerous specimens from the collection of diamonds in the possession of the present writer. From Mr. Pant's studies, it appears quite definitely that there is an inverse correlation between the primary effect in photo-conductivity and the luminescence of the diamond. Taking, for instance, the diamonds of the tetrahedral class, it is found that the more strongly luminescent they are, the smaller the photo-conductivity they exhibit. Indeed, the most feebly luminescent diamonds of this class exhibit the effect to an extent which is not vastly smaller than the non-fluorescent diamonds of the octahedral variety.

8. Some Concluding Remarks

Many of the physical properties of the allotropic modifications of diamond differ very little. Other properties, however, as we have seen, exhibit striking differences which enable us to distinguish between them. The luminescence exhibited under ultra-violet irradiation is by far the most easily observed and striking of these, and as already remarked, it exhibits most remarkable variations in colour and intensity. Numerous specimens in the possession of the writer even show variations of colour and intensity in different areas of one and the same specimen. These variations often take the form of bands and patterns of colour parallel to the octahedral cleavages of the crystal. The observations suggest that the tetrahedral and octahedral species of diamond may intermingle in the same specimen and that such intermingling is responsible both for the development of strain patterns and of luminescence patterns in the specimen. This is confirmed by the existence of corresponding local variations of the ultra-violet transparency of the diamond. The fuller consideration of these matters must be reserved for some future occasion.

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